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Project title:	Thrips Management in Desert Lettuce: Understanding Crop*Insect Interactions
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The goal of this project was to gather information on the biology and ecology of thrips, and to generate quantitative information on the impact of thrips on lettuce yield and quality. Ultimately this information will allow us to develop and implement new pest management strategies for thrips in lettuce. The funding for this project was received by the principle investigator on October 25, 2002. Research was initiated on September 2002 and research was concluded in June 2003.

Thrips Management in Desert Lettuce: Understanding Crop*Insect Interactions

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Abstract

Desert lettuce production remains highly dependant on the availability of effective IPM programs. The recent registration of several reduced risk insecticides now provides lettuce growers with a number of tools to effectively manage most insect pests (i.e., whiteflies, worms, aphids, and leafminers). However, thrips continue to cause problems, both for domestic and foreign market opportunities. . Because thrips have become an important pest of lettuce in the past few years, information needs to be generated that is specific to the desert. This includes an empirical knowledge of important host-crop relationships (sampling methods, damage and disease potential, and yield losses) and determining the developmental biology of thrips species for predicting outbreaks and movement. . The long-range goal of this research is to develop a sustainable insect management system that utilizes cultural, biological and chemical control tactics for thrips in Arizona lettuce. Thus, with the objective of ultimately developing a viable pest management approach that would enhance our present chemical tactics, this project was conducted to begin examining the seasonal ecology of thrips in Yuma.

Introduction

Desert lettuce production remains highly dependant on the availability of effective IPM programs. The recent registration of several reduced risk insecticides now provides lettuce growers with a number of tools to effectively manage most insect pests (i.e., whiteflies, worms, aphids, and leafminers). However, thrips continue to cause problems, both for domestic and foreign market opportunities. Because of the lack of empirical information on their biology and ecology, thrips may be the most important economic pest of winter lettuce grown in the desert. At the present time, lettuce growers rely almost exclusively on two insecticides, Lannate and Success, for their control. Not only is this approach expensive, but also places the industry at risk because of the increased threat of thrips developing resistance to these insecticides.

A significant research effort has been made to evaluate insecticide alternatives for thrips control, however, very little information is available on the biology and ecology of thrips in desert cropping systems. As a pest, thrips are unique on desert lettuce compared with other growing regions such as coastal California regions, Hawaii, or Florida where they are important disease vectors. Because thrips have become an important pest of lettuce in the past few years, information needs to be generated that is specific to the desert. This includes an empirical knowledge of important host-crop relationships (sampling methods, damage and disease potential, and yield losses) and determining the developmental biology of thrips species for predicting outbreaks and movement. Ultimately, a clear understanding of the seasonal ecology of thrips in desert cropping systems is essential before a viable pest management program for thrips on lettuce can be developed. The long-range goal of this research is to develop a sustainable insect management system that utilizes cultural, biological and chemical control tactics for thrips in Arizona lettuce. Thus, with the objective of ultimately developing a viable pest management approach that would enhance our present chemical tactics, this project was conducted to begin examining the seasonal ecology of thrips in Yuma.

Materials and Methods

Species Composition and Populations Dynamics in Desert Cropping System

Species Composition : Species composition was examined from beat pan samples taken in the temporal dynamics studies described below. Thrips adults were identified to species in 1 plot on each sampling date in each of the 6 plantings grown. Species identification was determined only for thrips adults because comprehensive keys to thrips larvae do not exist. Thrips adults were mounted individually on glass microscope slides and covered with glass slips. Thrips adults were identified to species based on morphological characteristics (Mound and Kibby 1998) utilizing a compound microscope (40X magnification).

Area-wide Thrips Activity: Information describing seasonal thrips activity on an area-wide basis was generated from a network of traps that were monitored weekly from late August through March. Traps were located at several sites throughout Yuma County's vegetable growing areas (see Figures 1-2 for locations). Three-five trapping stations were situated in the Yuma Valley, Gila Valley and Dome Valley/Roll areas for a total of 17 trap locations. At least one location in each growing area was situated near an AZMET weather station. The approximate location of traps in each valley was selected with the assistance of local PCAs. The crops being grown adjacent to each monitoring site was documented in September, December and March (Table 1). At each site, a single yellow sticky traps was placed in an open area adjacent or near a field where thrips were monitored. Traps were checked 1-2 times per week and were replaced every sample. Sticky traps were taken to the laboratory where all thrips were counted and recorded. Thrips species were not identified to species, with the exception of certain sample dates. Data from trap captures was converted to the mean number of adults / trap/ day and presented in a graphic format. In addition,

***Temporal Population Dynamics*:** Studies to examine the spatial and temporal abundance of thrips populations were conducted on head lettuce at the Yuma Agricultural Center, Yuma, Arizona. Beginning in mid-October, 0.25 acre plots of head lettuce were planted on about 2 week intervals. On each planting date (PD) lettuce was direct seeded into double row beds on 42 inch centers. Each planting was subdivided into 5 untreated plots and each plot consisted of 4 beds, 80 feet long. No insecticide applications were made during the study. Thrips populations were assessed by estimating the number of thrips adults and larvae / plant by taking relative beat pan samples 4-5 times throughout each planting beginning at thinning and ending at harvest. On each sample date, four whole plants (n=20 per sampling date) were selected at random in each plot and individually removed from the soil at ground level. Plants were then beat vigorously against a screened pan for a predetermined duration (5-10 hits for upper and lower plant portion). The pan measured 2" H by 15" L by 8" W and covered with meshed screen with 0.5 spacing. Inside of the pan was a yellow sticky trap (6" by 6") to catch and retain dislodged thrips. On samples collected at harvest, counts of heads and frame leaves were conducted separately. Head samples consisted of the head, with cap leaf and 2 wrapper leaves. The head was then split in two and beat against the screen also. Frame lead samples consisted of removing the head and 2 wrapper leaves and exposing as many leaves as possible while then beating the plant vigorously. Sticky traps were immediately covered with clear plastic and then taken to the laboratory where adult and larvae were counted under 10-20X magnification. Weather data was summarized for each sample date. Ambient temperatures for each AZMET site was prepared and provided graphically showing relative weekly trends across the season.

Sampling Thrips in Lettuce

Comparison Of Sampling Methods In Experimental Plots: Plots were established to provide untreated lettuce plants where the relative abundance of thrips populations could be estimated comparatively using each sampling method. Sampling was conducted in six separate plantings of head lettuce in 2002-2003 at the University of Arizona, Yuma Agricultural Center, Yuma, AZ. Varieties for each experimental plot were planted on the following dates: (PD 1) 'Wolverine' on 10 Oct; (PD 2) 'Grizzley' on 29 Oct; (PDS 3) 'Bubba' on 14 Nov, (PD 5) 'Diamond' on 3 Dec; and (PD 6) 'Diamond' on 12 Dec. On each planting date, lettuce was direct seeded into double row beds on 42 inch centers. Each planting was 16 beds by 150 feet long (0.2acre) and further divided into four plots of approximate equal size to provide replications for each sample method. Plot establishment and maintenance were similar to those used in commercial practices, with the exception that no pesticides were applied.

***Comparison Of Sampling Methods In Insecticide Efficacy Trials*:** The sample methods were evaluated in plots that received applications of insecticide shown to be effective in controlling thrips. Insecticides were applied on various timings depending on the efficacy trial. Four separate trials were conducted in the spring of 2003 at the Yuma Valley Agricultural Center to compare sampling methods in small plots of insecticide treated and untreated head lettuce and romaine. The planting date for each study included: 'Diamond' was planted in Head Lettuce I-west and Head lettuce II on 3 Dec, 'Diamond' was planted in Head lettuce II on 12 Dec, and 'PIC 417' was planted in Romaine on 10 Dec. Plots in each trial consisted of four beds, each bed 42 in wide and 50 ft long with a 7 ft buffer between plots. In all tests, the foliar applications were made with a CO_2 operated boom sprayer operated at 60 psi and 27 GPA. A directed spray (nozzles directed toward the plants) was delivered through 3 nozzles (TX-10) per bed. The sample methods were evaluated in plots that received applications of insecticide shown to be effective in controlling thrips. Insecticides were applied on various timings depending on the following efficacy trials.

Head Lettuce I West trial: Treatments were arranged in a randomized complete block design and replicated four times. The treatments consisted of an untreated control and two spray treatment regimes: 1) sprays applied at 7 day intervals and 2) sprays applied at 14 day intervals. The insecticide treatment regime used consisted of alternating between Lannate (0.75 lb/acre) mixed with Mustang (4 oz/acre); and Success (5 oz) mixed Mustang (4 oz) on each application. Both spray interval treatments were initiated on 19 Jan using the Lannate mixture first. The final spray in Treatment 1) was applied on 10 March and in Treatment 2) on 3 March.

Head Lettuce I East trial: Treatments were arranged in a randomized complete block design and replicated four times. The treatments also consisted of an untreated control and two spray treatment regimes: 1) 3 -spray applications delivered at 7 day intervals on 19, 26 Jan and 2 Feb and; 2) 2- sprays applied at a 14 day interval on 19 Jan and 2 Feb. The insecticide treatment used consisted of Success applied at 10 oz.

Head lettuce II and Romaine trials: Treatments were arranged in a randomized complete block design and replicated four times. The treatments consisted of an untreated control and four spray treatments: 1) Success applied at 6 oz; 2) Success applied at 10 oz; 3) Success at 5 oz mixed with Mustang at 4 oz; and 4) Lannate at 0.7 lb with Mustang at 4 oz. In the head lettuce trial, 2 applications were made on 26 Jan and 8 Feb, and in the Romaine on Jan 28 and 8 Feb.

Sampling Techniques: Three sampling techniques were used to estimate thrips abundance on lettuce relative to absolute counts. First, direct visual observations (Direct counts) of whole lettuce plants were made for relative estimates of thrips numbers. On each sample bout, five whole plants (n=20 per sampling bout) were selected at random in each plot and removed from the soil at ground level. On thinning, heading and pre harvest stage lettuce, direct counts consisted of counting all thrips adults and larvae observed on plants within a 2 minute period, beginning in the terminal area of the plant and working down the plant towards the older, basal leaves. Two people were used to collect the data, one person to count the thrips and another person recorded numbers and kept time. On samples collected at harvest, counts of heads and frame leaves were conducted separately. Counts consisted of 2 minute observations of heads beginning with the first 2 wrapper leaves and then working down towards the core. Count on frame leaves consisted of sampling the older leaves, beginning with lowest leaves. Samples were taken between 0900-1100 h.

The second relative sampling technique consisted of a Beat Pan method used to dislodge live thrips from plants. On each sample bout, five whole plants (n=20 per sampling bout) were selected at random in each plot and individually removed from the soil at ground level. Plants were then beat vigorously against a screened pan for a predetermined duration (5-10 hits for upper and lower plant portion). The pan measured 2" H by 15" L by 8" W and covered with meshed screen with 0.5 spacing. Inside of the pan was a yellow sticky trap (6" by 6") to catch and retain dislodged thrips. On samples collected at harvest, counts of heads and frame leaves were conducted separately. Head samples consisted of the head, with cap leaf and 2 wrapper leaves. The head was then split in two and beat against the screen also. Frame lead samples consisted of removing the head and 2 wrapper leaves and exposing as many leaves as possible while then beating the plant vigorously. Sticky traps were immediately covered with clear plastic and then taken to the laboratory where adult and larvae were counted under 10-20X magnification.

The third relative sample involved placing Yellow sticky traps and Blue sticky traps (3" by 5" in size) at canopy level within each plot. On each sample bout, a single yellow and blue sticky trap was set 6 ft from each other near the center of each plot. Traps were kept in the plots from 0600 h to 1700 h. Following each trapping period, traps were taken into the laboratory and the numbers of adults on the entire trap surface were counted under 10-20X magnification.

Absolute population abundance was determined by using whole plant washes. On each sample bout, five whole plants were selected at random in each plot and individually removed from the soil at ground level. Then each plant was placed individually into a 5 gal plastic container and immediately sealed with a removable lid. Each container contained a solution of 3 gal water, 2 oz of dilute liquid detergent and 5 oz of ethanol. In the laboratory, the plants

were vigorously agitated in each sealed container for 30 sec intervals over the course of a 2 hr period. Following extended agitation, the aqueous contents of the container were poured and filtered through a fine meshed coffee filter (500 mesh) which was held by a no.30 metal sieve. Plants were then dissected and each leaf from each plants was thoroughly washed with water within the confines of the container and funneled through the meshed filter. After washing all plant parts and straining the remaining water, filters were placed on 12" diameter paper plates and placed in 2 gallon plastic bags. Bagged filters were placed into a freezer for 24 hrs, after which all thrips adult and larvae on each filter were counted under 10-20X magnification.

Statistical Analysis: The association of thrips abundance from the three sampling methods and absolute counts from plant washes was measured with Pearson's correlation coefficient. Sampling precision for the three methods was estimated in each field by calculating the relative variation (RV) on each sampling date. The RV values were calculated as RV=(SEM/mean)100, where SEM=standard error of the mean. To compare differences in relative variation between sampling methods, mean RV values were calculated by averaging the weekly RV estimates in each field and compared using analysis of variance and the Ryan-Einot-Gabriel-Welch Multiple Range Test. Sampling efficiency was also calculated for each technique as the relative net precision (RNP) where RNP=100/[(RV_m)(c_u)], where RV_m =mean relative variation and c_u= cost in minutes to count thrips abundance on an individual sample unit, or mean search time. Larger RNP values indicated greater sampling efficiency. Mean RNP and search times were calculated for each sample method in the experimental plots to provide a wide range of adult densities. Data collected from the chemical trials were first transformed to $\log_{10}(x+1)$ before statistical analysis because of large differences in variances among treatment means. Differences in thrips counts among insecticide treatments were determined with a repeated-measures analysis of variance (ANOVA) and paired t-tests. The model was used to test for insecticide treatment main effects along sampling dates. When differences were found, means were separated by the Ryan-Einot-Gabriel-Welch Multiple Range Test.

Thrips*Damage* Yield Relationships

Yield*damage studies in head lettuce were established in plots that received varying applications of insecticide to create differences in thrips abundance. In addition, cages were used to exclude thrips in the romaine study. Insecticides were applied on various timings depending on the trial. Two separate trials were conducted in the spring of 2003 at the Yuma Valley Agricultural Center to evaluate thrips abundance on scarring and damage to head lettuce The planting date for each study included: 'Diamond' was planted in both head lettuce on 3 Dec and 'PIC 417' was planted in Romaine on 10 Jan. Plots in each trial consisted of four beds, each bed 42 in wide and 50 ft long with a 7 ft buffer between plots. In all tests, the foliar applications were made with a CO_2 operated boom sprayer operated at 60 psi and 27 GPA. A directed spray (nozzles directed toward the plants) was delivered through 3 nozzles (TX-10) per bed. The sample methods were evaluated in plots that received applications of insecticide shown to be effective in controlling thrips. Insecticides were applied on various timings depending on the following efficacy trials.

Trial 1.: Treatments were arranged in a randomized complete block design and replicated four times. The treatments also consisted of an untreated control and two spray treatment regimes: 1) 3 -spray applications delivered at 7 day intervals on 19, 26 Jan and 2 Feb and; 2) 2- sprays applied at a 14 day interval on 19 Jan and 2 Feb. The insecticide treatment used consisted of Success applied at 10 oz.

Trial 2: Treatments were arranged in a randomized complete block design and replicated four times. The treatments consisted of an untreated control and two spray treatment regimes: 1) sprays applied at 7 day intervals and 2) sprays applied at 14 day intervals. The insecticide treatment regime used consisted of alternating between Lannate (0.75 lb/acre) mixed with Mustang (4 oz/acre); and Success (5 oz) mixed Mustang (4 oz) on each application. Both spray interval treatments were initiated on 19 Jan using the Lannate mixture first. The final spray in Treatment 1) was applied on 10 March and in Treatment 2) on 3 March.

Romaine cage trials: Treatments were arranged in a randomized complete block design and replicated four times. The treatments consisted of an untreated control, two spray treatments: 1) weekly sprays and 2 Bi-weekly sprays where the insecticide treatment regime used consisted of alternating between Lannate (0.75 lb/acre) mixed with Mustang (4 oz/acre); and Success (6 oz) on each application. Sprays were initiated on Feb 4 and terminated on Mar 22. A final treatment consisted of excluding thrips from plants by using framed cages (5 ft *3 ft *3 ft) screend with a fine mesh. Asingle cage was placed over 8 romaine plants in the untreated check just following thinning and maintained there until harvest.

Thrips abundance at each evaluation was determined by using whole plant washes as described above. Scarring was measured by rating the amount of scarring found on the outer leaf tissue of each plant leaf. In trial 1 and 2 at the pre-heading stage a rating from 1-4 was used to document scarring where, 1=1-10% of the leaf surface showed visible signs of feeding injury (scarring), 2=11-20%, 3= 21-40 %, and 4= greater than 40%. Midrib bronzing was also

measured by estimating the % of leaves on the entire plant where discolored feeding scars were noticeable on the lower midrib portion of the main vein on each leaf. At harvest in Trial 2, scarring damage midrib bronzing was only rated on the youngest 7 wrapper leaves, 3 cap leaves and the butt area. The damage rating was a s follows: 1= 0-4% of the leaf surface showed visible signs of feeding injury (scarring), 2= 5-10%, 3=11-20%, and 4=>20%.

In the romaine trial, scarring and midrib bronzing were measure similar to the head lettuce trials at preheading. In addition, yields were measures by counting the total number of leaves / plant, the number of marketable leaves (no visible scarring or bronzing), and whole and trimmed (scarred and bronzed leaves removed)plant weights. Differences among treatments were detected with ANOVA, and means were separated by the Ryan-Einot-Gabriel-Welch Multiple Range Test.

Results and Discussion

Species Composition: A total of 380 thrips adults were examined over 26 samples dates and identified to species. Western flower thrips, *Frankliniella occidentalis* was the most common species observed on lettuce plants across all sample dates in the plant surveys. This species was overwhelmingly the predominant species found in lettuce, accounting for > 94% of the thrips adults sampled in all instances. This was expected, as western flower thrips are considered the most important thrips species present on lettuce worldwide. The onion thrips, *Thrips tabaci*, was found to be present in 2.9 % of the samples. These adults were found predominantly in the early fall and again in the fall on smaller lettuce plants. The lack in numbers suggests that they do not utilize lettuce as a primary host. Several other thrips species were tentatively identified on lettuce plants during the study. These include *Chirothrips falsus* (a pest of bermudagrass seed), the six spotted thrips, *Scolothrips sexmaculatus* (a mite-aphid predator), the bean thrips, *Caliothrips fasciatus*,(found in the spring, common in citrus and cotton), and the citrus greenhouse thrips, *Heliothrips haemorrhoidalis*, during January. However these thrips were found in very low numbers, and only accounted for 1.7% of the total thrips examined during the season. There were also a few individuals (n=14) that we were unable to identify.

Area-wide Thrips Activity: Thrips activity in each of the three Yuma growing areas is shown in Figures 1-3. Thrips movement throughout the growing season varied between each location (Table 1). In the Gila valley, thrips adults were caught on sticky traps most frequently during the fall, and in lower numbers in the late spring. Populations in the Dome Valley appeared to be most active in the fall (Figure 1). In contrast, thrips were most active during late spring in the Yuma Valley coinciding with the reduction of lettuce acres (Figure 2). Among the 3 areas, thrips have been comparatively more active during the fall in the Dome and Gila Valleys, whereas in the Yuma Valley, thrips have been consistently more active during the late spring. The differences in thrips movement measured among the growing locations are largely a reflection in lettuce plantings and differences in cropping patterns (Table 1).

***Temporal Population Dynamics*:** Seasonal population abundance of thrips adults and larvae during six lettuce planting dates over a two year period in 2002 and 2003 is shown in Figures 4-6. These data show that thrips reproduction and development on lettuce is influenced by temperature. This can be seen for each life stage within each planting where population abundance was greatest during the 1st Sep planting and then again during the later planting where temperatures averaged 60-65 degrees F. Population development was at its lowest level during the cooler winter periods. In addition, greater development and abundance of thrips during the winter and spring in 2003, compared with 2002, can largely be attributed to warmer temperatures in Dec, Jan and Feb. This data suggests that during cool winters October lettuce planting are at a lower risk of thrips infestation compared to mild winter conditions experienced in 2003 where all lettuce planting experienced significant thips development and abundance. Finally, this data demonstrates that western flower thrips is capable of reproducing and developing large population densities on head lettuce under winter and spring growing conditions in the desert.

Sampling Thrips in Lettuce – Comparison of Methods in Experimental Plots. In general, the beat pan and direct count sampling methods indicated population trends similar to the plant washes throughout the season in experimental plots (Fig 7-9). As expected, plant washes consistently estimated the greatest number of adults and larvae per sample. In most cases, estimates of thrips abundance were greater for beat pans than for direct visual counts. For all methods, populations were low early in the season and increased as the plant matured. Populations peaked for in PD 3 and 4. Between the two sticky traps, blue cards usually caught more thrips that yellow cards, particularly when adult populations were high (Figure 10).

Linear correlations were significant for the comparisons between the relative estimates and the plant washes (Fig.11-13). All sampling methods were significantly correlated with the absolute estimates of thrips obtained with the plant washes, although the beat pan showed stronger correlations than either direct counts and sticky traps. Similarly, a strong correlation was observed for adult abundance measured with between yellow and blue sticky traps (Fig 14).

Mean thrips abundance and RV values calculated from beat pan, direct counts and plant washes varied with crop stage and thrips lifestage. (Table 2-4). For adults, abundance was low at thinning stage, but significantly lower in direct counts. At subsequent crop stages, abundance was greatest in the plant washes, and in some cases, had lower RV values. Peak abundance was observed at the early heading stage. Similar trends were observed for larvae and total thrips abundance, but peak abundance was measured at harvest stage. RV values did not vary as much among the methods for larvae at the crop stages as was observed among adults. RV values calculated for the sticky traps were generally much higher than observed for the other methods and often exceed a value of 100. Estimates of RNP from the experimental plots varied with thrips abundance and sampling method (Table 2-4). With the exception of the fixed 2-minute search time for direct counts, sampling costs (mean search times) were directly proportional to increases in thrips density, resulting in higher sampling efficiencies for the beat pan methods relative to plant washes. RNP values for direct counts were consistently higher across all thrips life stages and head lettuce crop stages.

Reliability of Sampling Methods in Efficacy Trials.

Head Lettuce I West and East Trials: Thrips adult and larvae numbers per plant were measured on 6 Feb following 2 and 3 sprays for the 14 and 7 day interval treatments, respectively (Table 5). Plants had not begun to yet form heads. Although the absolute estimates (plant washes) of adult and larvae thrips numbers were greater than direct count or beat pan sampling, all three methods estimated similar differences among the three spray treatments. There was some discrepancy among methods in the estimation of treatment differences for total thrips where direct counts indicated significant differences between the two spray regimes. Similarly, comparison among the sampling methods in control (% reduction of thrips compared with the untreated control), indicated that direct counts significantly underestimated control of total thrips (Fig 15A). In the Head Lettuce- I East trial all three methods estimated similar differences among the three spray treatments (Table 7), and similarly provided comparable estimates of thrips control for each treatment (Fig 15B).

At harvest stage in the Head Lettuce I-West trial, the sampling methods provided more variable estimates of treatment differences of thrips adults and larvae (Table 6). Both the direct count and beat pan methods incorrectly estimated treatment differences of adults and larvae relative to the absolute plant wash estimates. For a adults, both methods failed to detect higher numbers in the 7 day regime, and failed to detect differences in larvae numbers between the two spray regimes. Comparisons among the sampling methods for thrips control in the 14 d spray interval treatment indicated that direct counts significantly overestimated larval control, and both relative methods overestimated estimated total thrips control (Fig. 15C). All three sampling methods provided similar estimates of thrips control in the 7-day spray interval treatment.

Head lettuce II and Romaine Trials: In both crops, the beat pan method provided different estimates of treatment differences for adult thrips (Table 8-9) . Beat pan sampling in head lettuce indicated that both Success +Mustang and Lannate +Mustang treatments had significantly lower adult numbers than the untreated control, whereas the absolute plant wash counts estimated no differences among treatments. Similarly, in the romaine trial, beat pan sampling estimated that thrips adult numbers in the Success 10 oz treatment di not differ from the untreated control, wheres treatment differences between the Success treatment and check using plant wash sampling were significant. Both sampling methods provided comparable estimates of treatment differences for thrips larvae (Table 8-9). Comparisons between the two sampling methods for thrips control in the head lettuce indicated that beat pans provided statistically reliable estimates of thrips control for all four spray treatments (Fig. 16A). However, in the romaine trial, beat ban samples significantly under estimated % control of thrips adults in Lannate+Mustang treatment (Fig 16B).

This study showed that relationships between relative sampling methods and absolute counts of thrips abundance were fairly consistent in untreated experimental plots. In most cases, direct visual counts and beat pan sampling provided comparable measures of changes in population abundance through the cropping season and were strongly correlated with absolute densities However, both relative methods could only account for a proportion of the thrips infesting head lettuce plants. Based on linear regressions (Fig 11-12), beat pan sampling and direct counts were only able to estimate about 30% of the actual absolute population. This discrepancy between estimates was even grater

for larvae. On the average, beat pan sample estimated about 18-20% of the actual population density, whereas direct visual counts accounted for less than 10% of the thrips present. This information clearly illustrates the cryptic nature of immature thrips and reflects their life cycle on lettuce. More importantly, PCAs should be aware that their discovery of light-moderate numbers of adults and thrips on lettuce may indicates a larger number actually present within leaf margins deep within the plant interior.

Individual adult thrips captured on sticky traps did not always represent the same populations estimated with beat pan and direct counts. Sticky trap counts may reflect both trivial movements within the field, as well as dispersing adults moving in and out of fields. Trap counts are also influenced by the attraction of whiteflies to color. In this study, thrips were generally more attracted to the blue traps, but yellow traps reflected comparable changes in population abundance throughout the season and were strongly correlated with trap counts for blue traps (Fig 14). Unfortunately, adults estimates with both traps were poorly correlated with absolute densities found on plants.

Conclusions drawn from the RV and RNP estimates depend on the specific needs of the researcher and should be carefully interpreted. Plant washes provided the most consistency in sampling precision, but in some cases beat pan sampling provided significantly better precision. Precision for direct counts tended to vary throughout the season and between lifestage. This is not surprising, particularly for adults, considering that plants are handled for sustaine periods of time and allow thrips to escape from the plant. In general, sampling precision for sticky traps was inconcistent, probably a consequence of their dispersal behavior within small experimental plots. When considering sampling efficiency in terms of cost, direct counts always provided greater efficiency. This was a direct result of less time was required to sample compared with beat pans and plant washes. For practical reason, direct counts may provide good estimates of relative population abundance.

Comparison of sampling methods in the insecticide efficacy trials indicated that beat pan and direct visual counts were not always reliable for estimating treatment differences of adult thrips. The failure to accurately detect differences in adults with these methods was likely a result of both insecticide repellency and inadequate spatial isolation between plots. Inter- and intra-plot movement of adults was likely a major source of error that resulted in adult densities in treated and untreated control plots to be incorrectly estimated. Migration of adults into and out of the experimental plots from surrounding crops and weeds could also have biased the counts. For densities of thrips larvae however, beat pan and visual counts methods did provide accurate estimates of treatment differences. These data suggest that post treatment evaluation of thrips densities will vary between adults and larvae and should be carefully evaluated, especially when pyrethroids have been applied.

In conclusion, relative to the absolute plant wash counts, the beat pan procedure provided better population estimates than either direct visual counts or sticky traps because they more accurately reflected adult abundance on plants and provided acceptable levels of sampling precision. Both beat pan and direct visual count procedures are reliable thrips sampling methods that will generally provide dependable estimates of thrips abundance necessary in lettuce pest management programs. Furthermore, these methods, and the beat pan in particular, also may serve as effective research tools that provide reliable estimates of treatment differences.

Thrips*Damage* Yield Relationships:

Head lettuce:

Results from both of the head lettuce trials clearly demonstrated a strong relationship between thrips infestations and associated leaf scarring and mid-rib bronzing in pre-heading stage lettuce (Table 10-11). Although differences in thrips were not seen between the two spray interval treatmenst, in most cases, the weekly sprays resulted in less leaf scarring and fewer damaged mid-ribs. This is probably due to the additional time thrips were allowe to feed on leaves between sprays in the bi-weekly treatment. In both trials, the untreated lettuce plants had thrips densities about 5x and 10x higher numbers of adults and thrips, respectively, than the sprayed treatments. These high densities resulted in excessive scarring on the leaves, where most leaves had more than 25% of their surface area damaged. Interestingly, midrib bronzing was high even in the weekly sprays suggesting that this damage ocurrs at low population levels and probably primarily by adults.

A similar response was observed at harvest in trial 2 where damage and scarring rating were taken from harvestable portions of lettuce heads. Weekly and biweekly sprays were able to maintain thrips larvae numbers to significantly lower levels that the untreated plots. Consequently, large larval populations found in the untreated plants resulted in

significantly more scarring damage and mid-rib bronzing (Table 12). Because adult numbers were similar for all treatments, we assume that larvae are largely responsible for the differences in damage. This data leads us to conclude that cosmetic damage to lettuce heads at harvest stage can be avoided by preventing significant immature thrips colonization throughout the season. This is further illustrated in Figures 18 and 19 which shows damage ratings for each treatment on each wrapper and cap leaf. Damage to weekly sprayed treatments was below or slightly above a damage rating of 1.0, whereas untreated thrips population caused significant scarring on untreated leaves.

Romaine Cage Test:

In this study, caged plants were used to exclude thrips throughout the growing season. In addition, weekly and biweekly sprays were applied to maintain thrips numbers at low-moderate levels. These treatments created a gradation in thrips densites ranging from less than 60 thrips / plant in the cages to greater than 1300 / plant in the untreated check (Table 14). The cages did not completely exclude the thrips, but the low numbers experienced at harvest caused very little scarring damage or mid-rib bronzing to the romaine plants (Table 15). In contrast, insecticide sprays significantly reduced the amount of scarring on leaves, but did not significantly reduce mid-rib bronzing compared with the untreated check. Yields were greatest in the cages, in part due to protection from thrips, but also due to enhanced growing condition.

The weekly sprays resulted in lower thrips larvae than the biweekly regime and the untreated control. Consequently, these lower densities resulted in significantly more marketable leaves and a greater trimmed weight per plant than plants in the biweekly treated plots and the untreated check (Table 15). Although the biweekly sprays had fewer thrips than the untreated check, differences in yields were not detected. Distribution of leaf scarring and mid-rib bronzing in romaine plants at harvest also shows the relationship between thrips infestation levels and damage. In all cases, scarring damage by thrips is greatest on the lower half of the plant. Damage in the weekly sprayed plants was greatest in the middle third of the plant. In contrast, mid-rib bronzing was consistently evident to the 15th leaf in all plants. The weekly sprayed plots maintained fewer damaged leaves only in 5-6 fewer leaves. Again, because of the similarity in adult numbers among the sprayed and untreated plants, it can be concluded that adults are the primary life stage responsible for mid-rib bronzing in romaine plants.

Conclusion: Results from this research validate observations made by many growers and PCA's. First, thrips are ubiquitous in our desert cropping system, occurring across many growing areas regardless of cropping patterns. Temperature plays an important role in their dispersal, reproduction and population development. In several situations, thrips abundance exceeded more than 1000 per plant in both head and romaine lettuce plantings. They are capable of rapidly building up to large damaging levels. Second, we have found that sampling for thips can be time-consuming, but can yield practical information. Direct observations account for only about 10% of the actual population densities. This sampling technique can be used by PCA's and growers to make management decisions when taking into account this underestimation. Beat pan sampling, although not very practical for PCA's was shown to be a reliable and precise method for measuring thrips abundance for research purposes. Finally, sticky traps were shown to be useful in monitoring adult thrips activity. Finally, based on small plot and cage studies, it was demonstrated that thrips larvae have a great potential for causing cosmetic damage to head lettuce throughout the season, and particularly at harvest if not managed properly. Romaine lettuce is even at higher risk, where thrips feeding can result in excessive trimming and reduced plant weights due to both adult and immature damage.

Table 1. Description of the cropping patterns associated with trap locations, 2002-2003

		Fields Adjacent to Traps		
Site	**Loc**	**Sep-Oct**	**Dec-Jan**	**March-Apr**
Yuma Valley	1	Broccoli, Fallow	Broccoli, Wheat	Cotton, Melons, Lettuce
	2	Fallow, Cotton	Lettuce, Fallow	Cotton, Fallow, Lettuce
	3	Cotton, Fallow	Broccoli, Melons	Melons, Fallow
	4	Fallow	Lettuce, Broccoli	Wheat, Cotton
Gila Valley	1	Fallow, Sudan	Broccoli, Fallow	Cotton, Lettuce, Fallow
	2	Cotton	Lettuce, Fallow	Wheat, Cotton, Fallow
	3	Fallow	Lettuce	Wheat, Cotton
	4	Alfalfa, Fallow	Alfalfa, Lettuce	Alfalfa, Fallow
	5	Alfalfa, Lettuce	Alfalfa, Lettuce	Alfalfa Fallow
Dome Valley	1	Alfalfa, Lettuce	Alfalfa, Fallow	Wheat, Cotton
	2	Fallow	Lettuce	Wheat, Fallow
	3	Sudan, Lettuce	Lettuce, Fallow	Cotton
	4	Sudan, Fallow	Lettuce, Broccoli	Broccol, Cotton
	5	Alfalfa, Fallow	Alfalfa, Broccoli	Alfalfa, Cotton

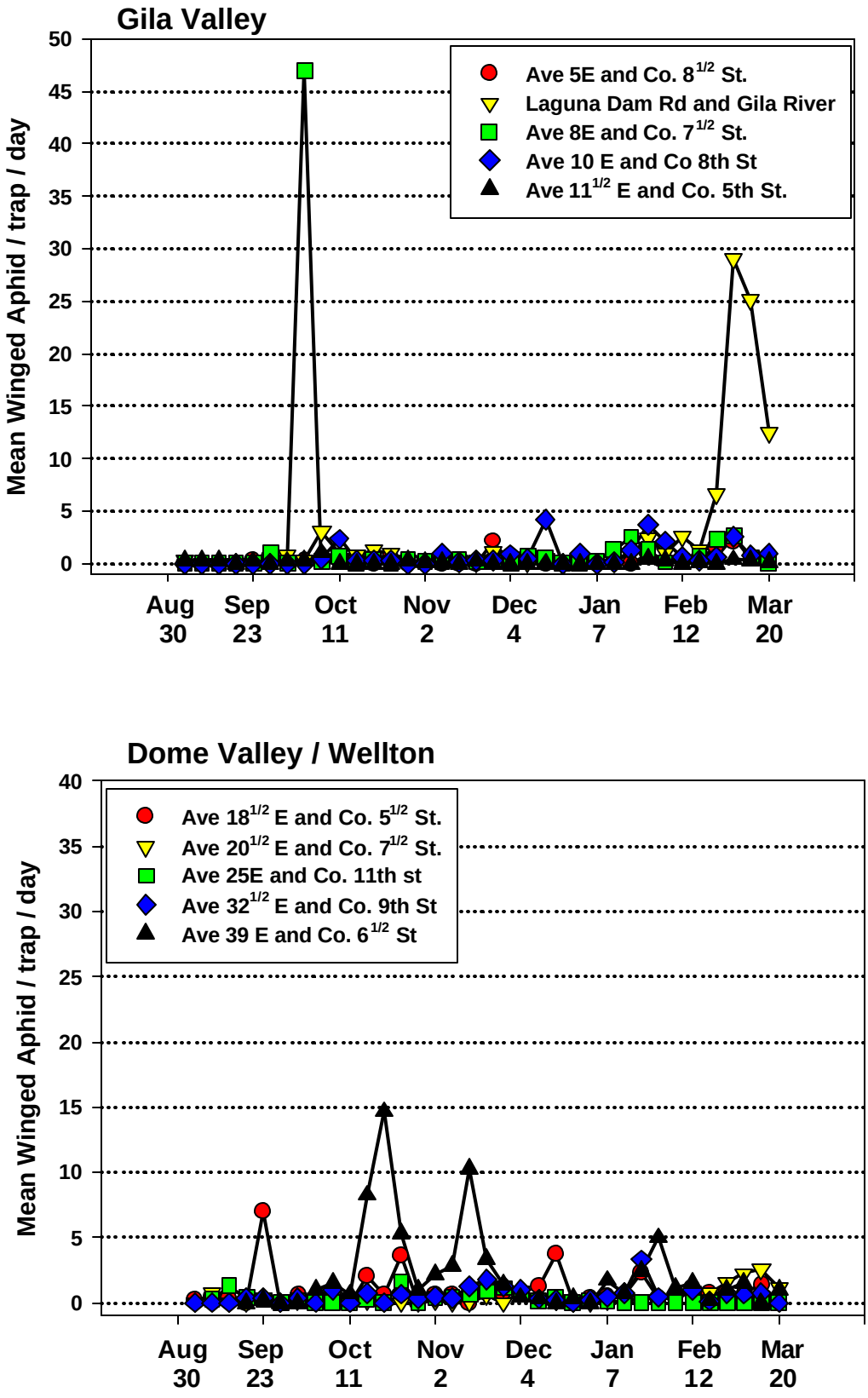
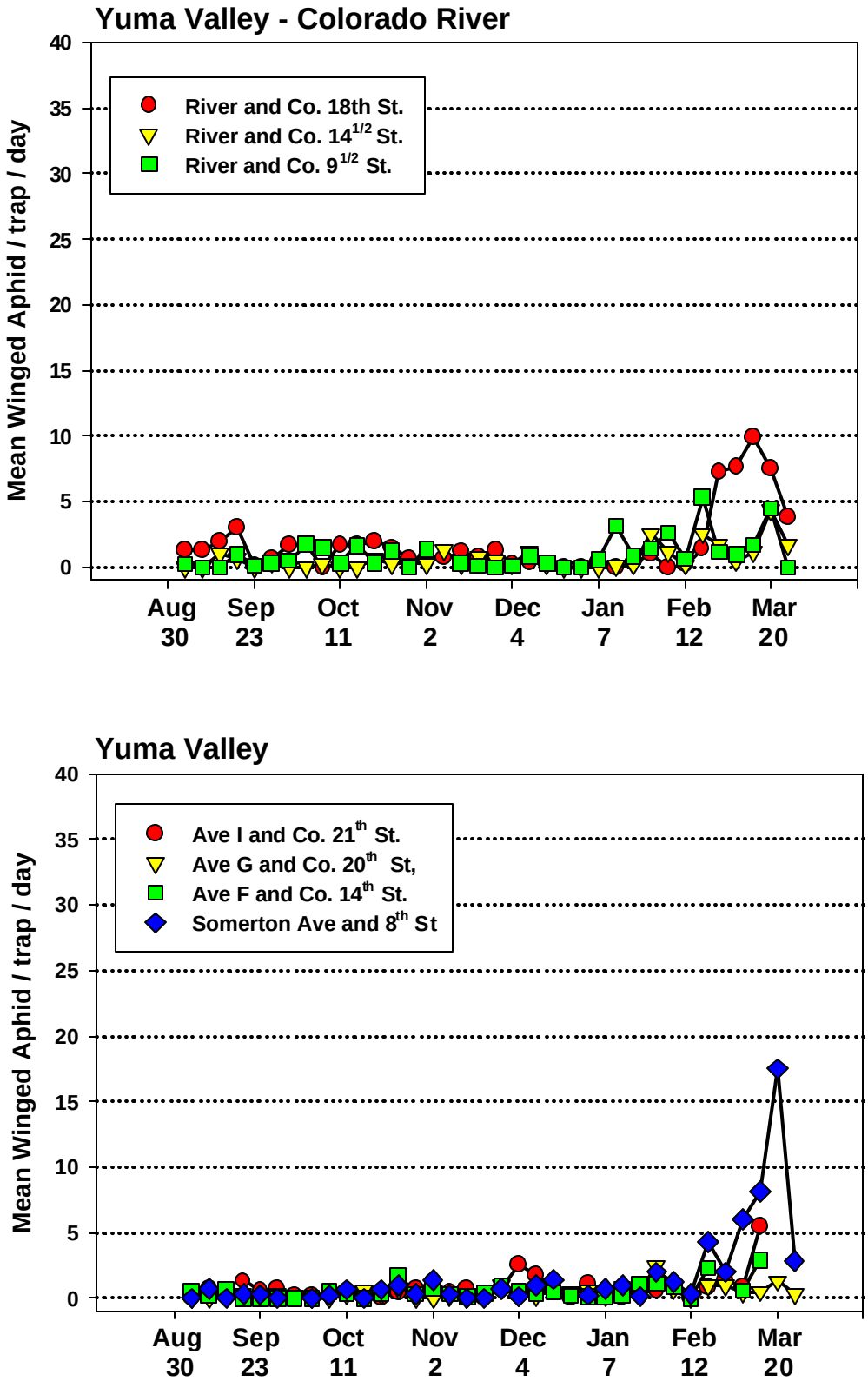


Figure 1. Seasonal thrips activity as measured by yellow sticky traps

Figure 2. Seasonal thrips activity as measured by yellow sticky traps



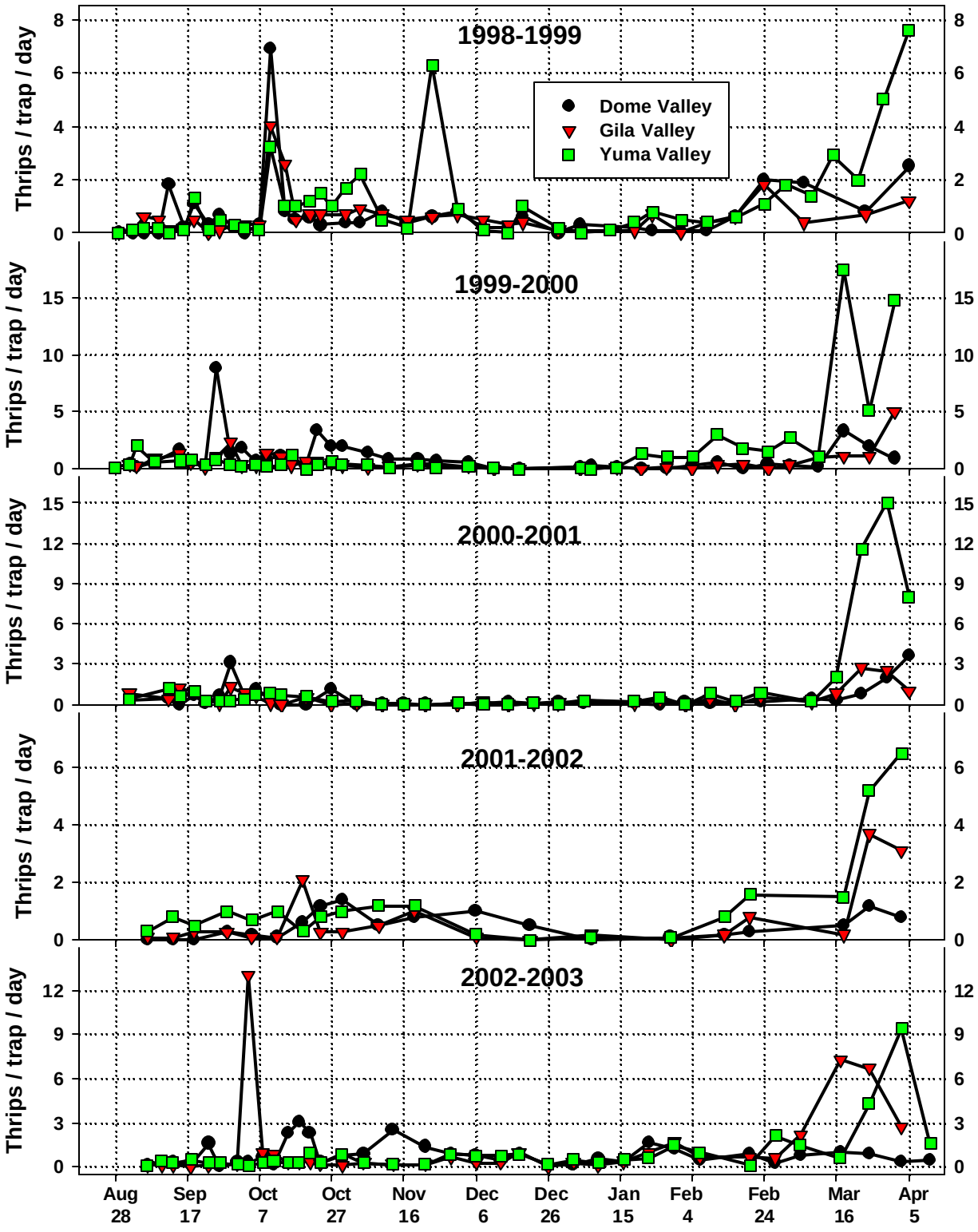


Figure 3. Seasonal thrips activity as measured by yellow sticky traps

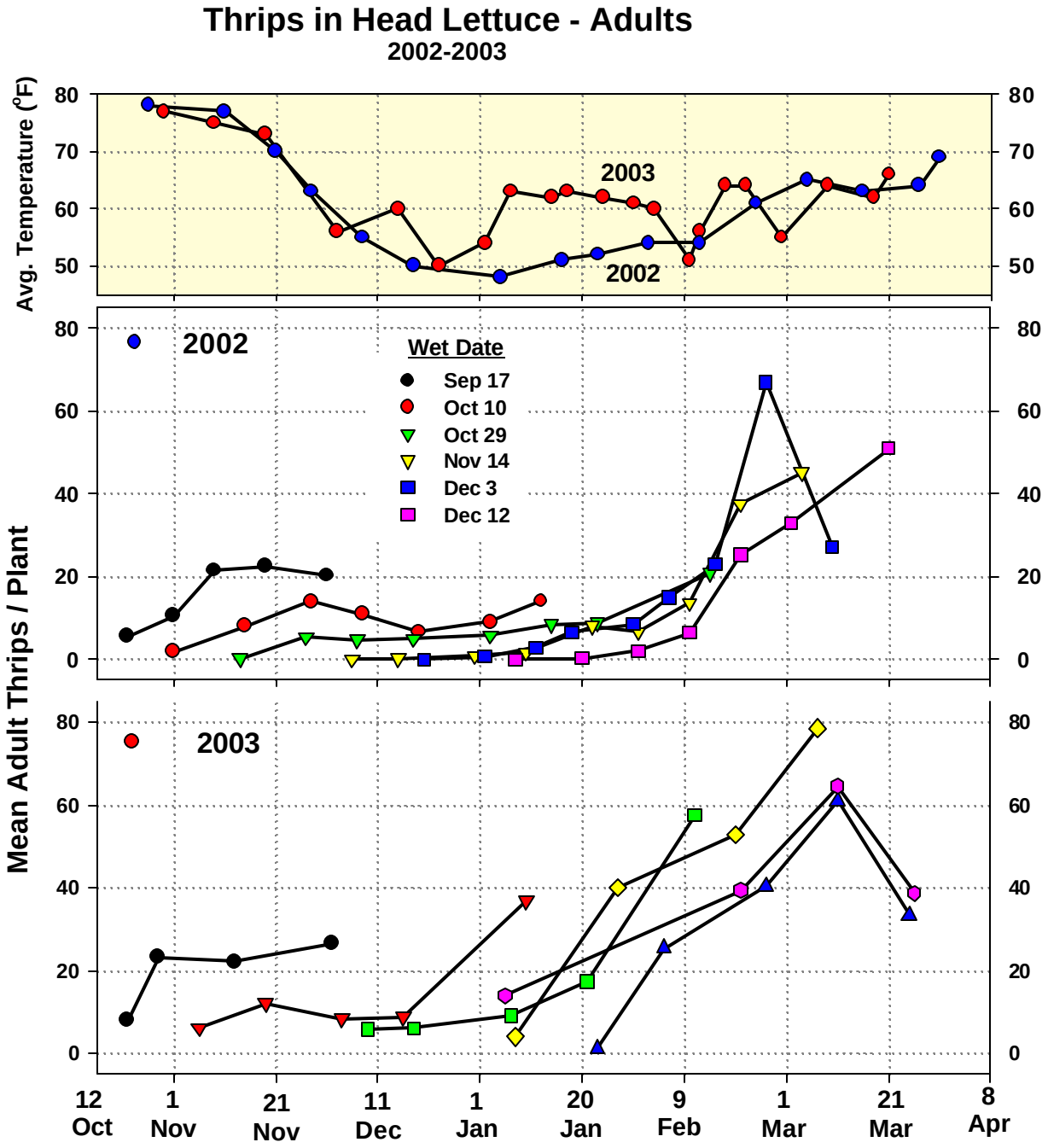


Figure 4. Population trends of thrips adults estimated with beat pan samples in six experimental lettuce plantings over 2 years, Yuma Agricultural Center.

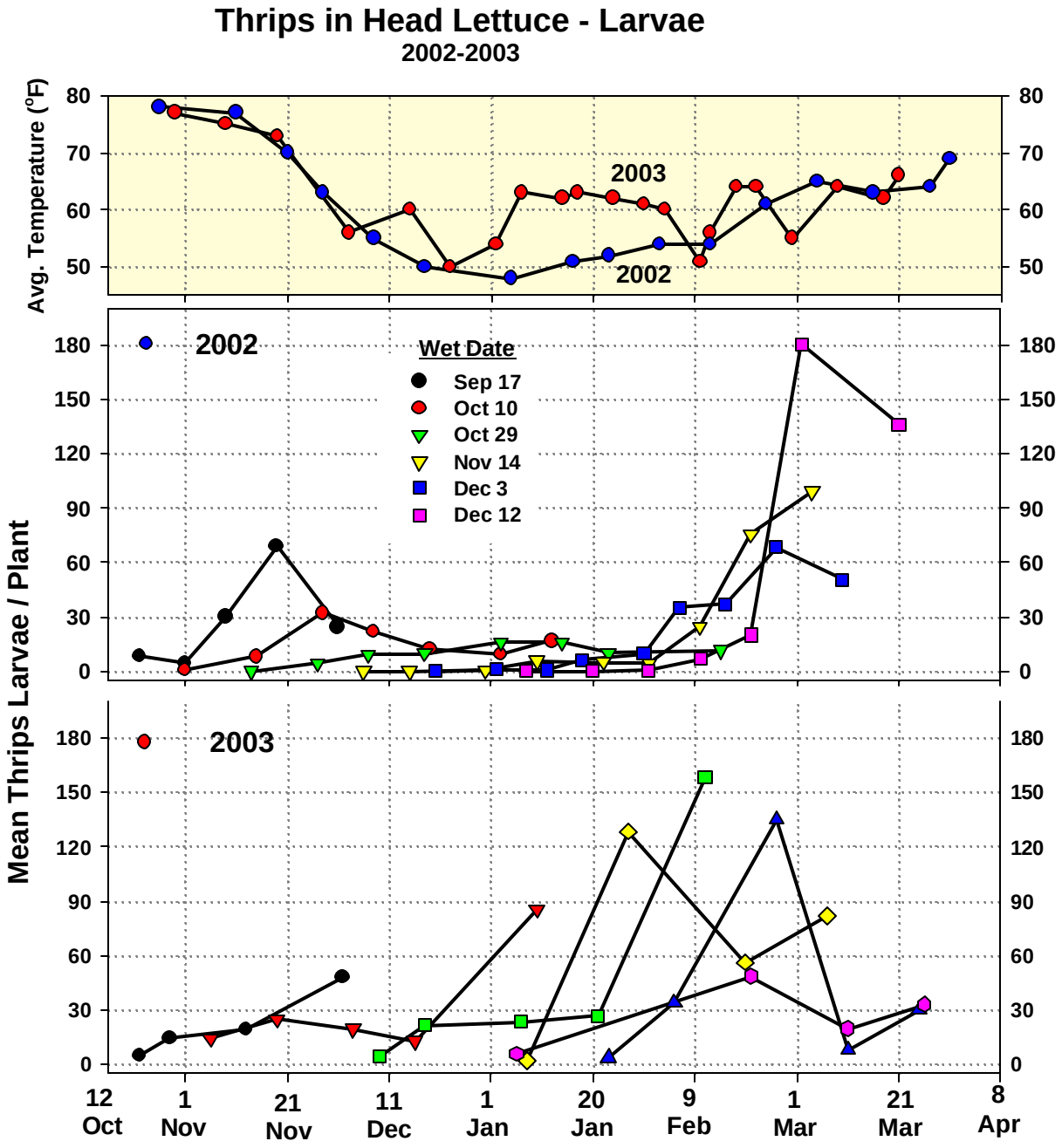


Figure 5. Population trends of thrips larvae estimated with beat pan samples in six experimental lettuce plantings over 2 years, Yuma Agricultural Center.

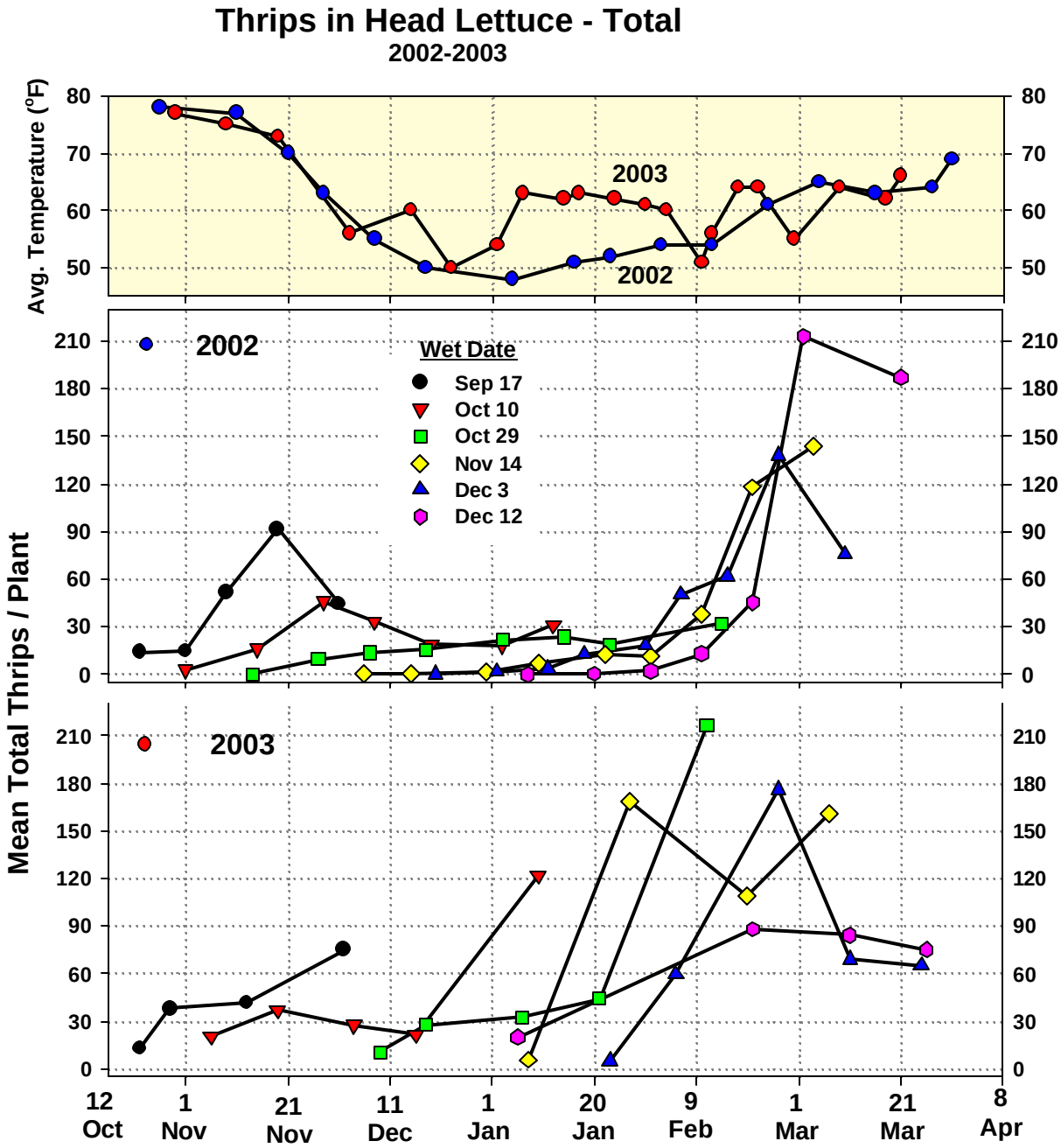


Figure 6. Population trends of total thrips estimated with beat pan samples in six experimental lettuce plantings over 2 years, Yuma Agricultural Center.

Figure 7. Population trends of thrips adults estimated with beat pan, direct counts and plant wash sampling in six experimental lettuce plantings , Yuma Agricultural Center, 2002-2003.

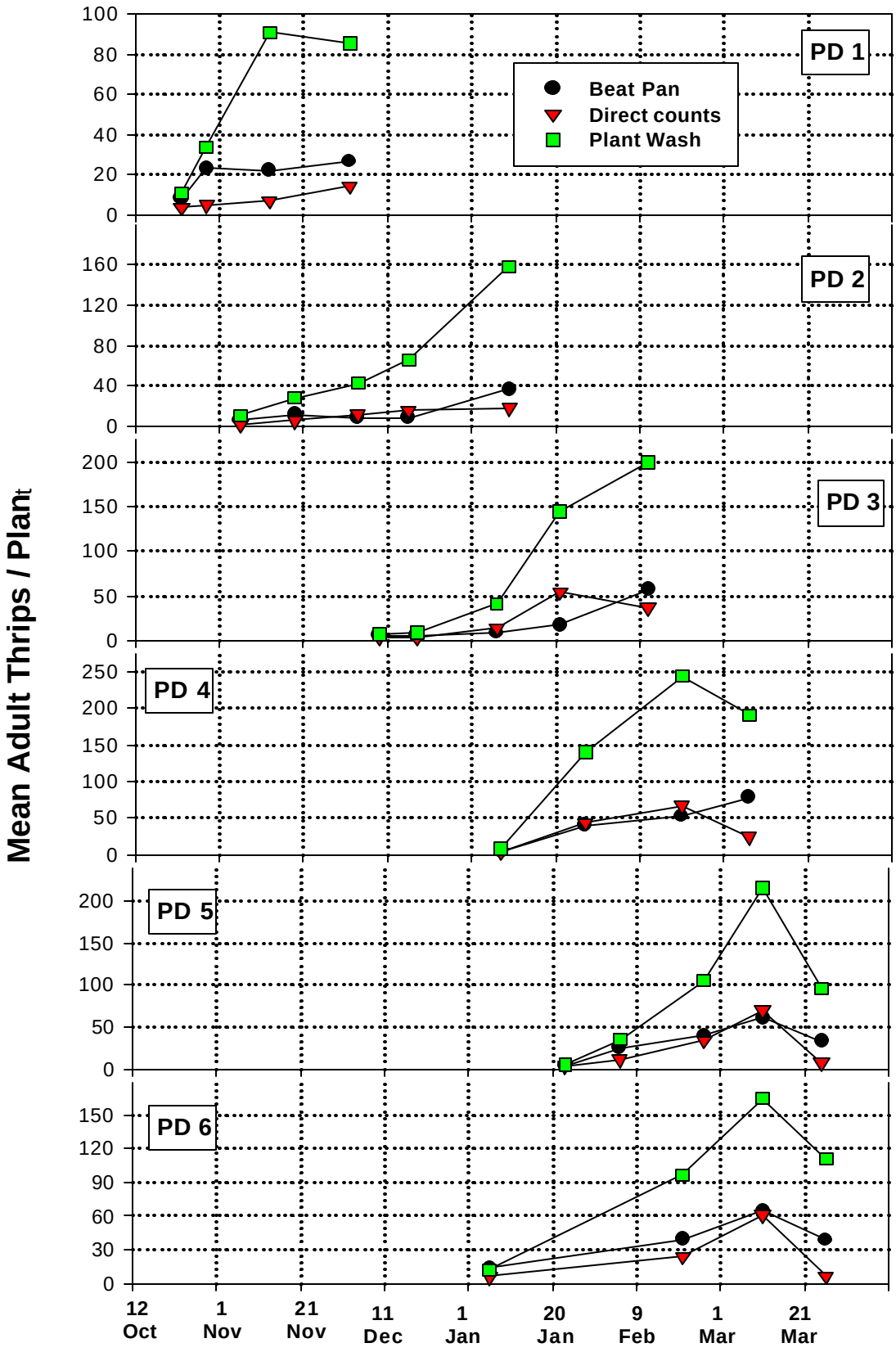


Figure 8. Population trends of thrips larve estimated with beat pan, direct counts and plant wash sampling in six experimental lettuce plantings , Yuma Agricultural Center, 2002- 2003.

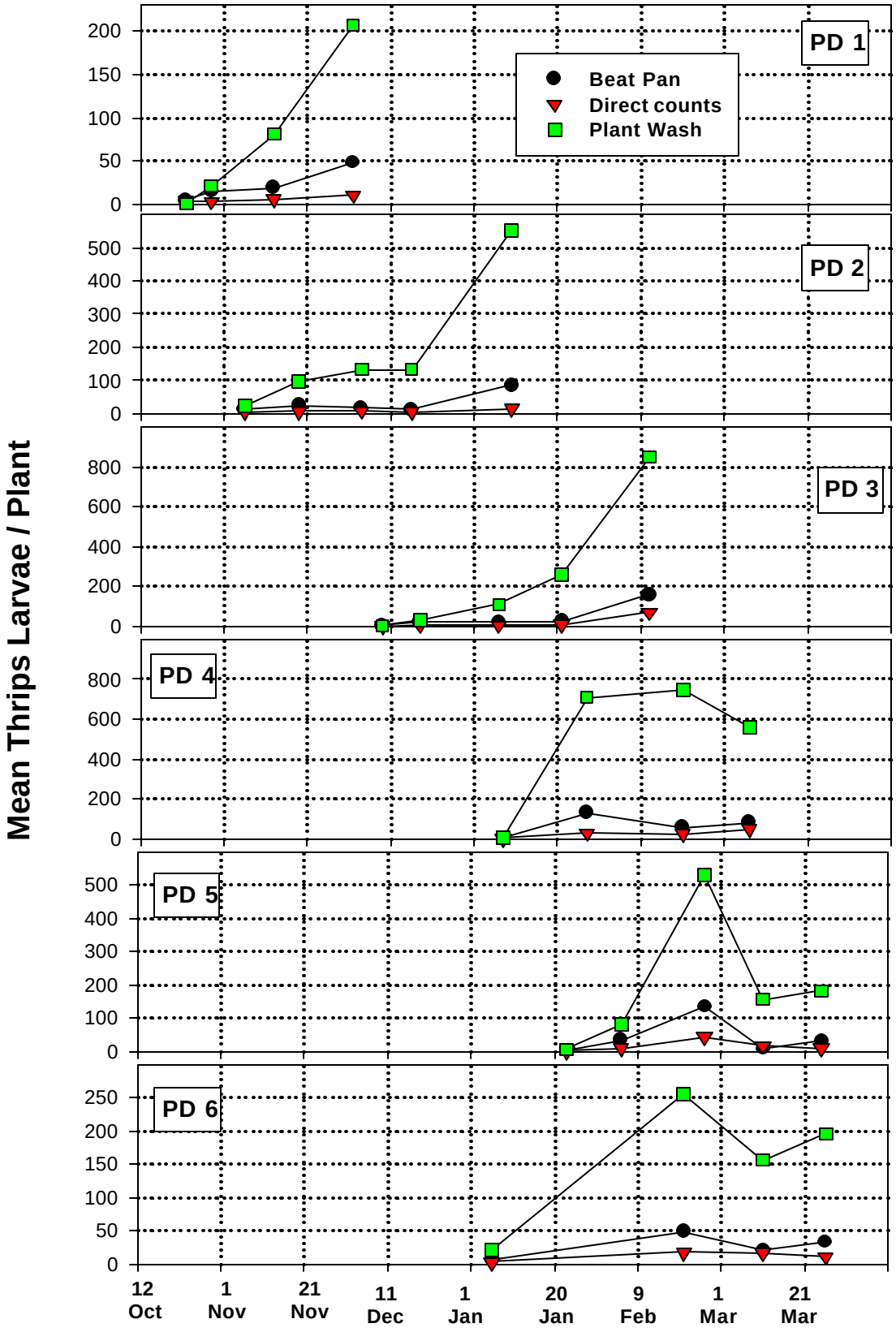


Figure 9. Population trends of total thrips estimated with beat pan, direct counts and plant wash sampling in six experimental lettuce plantings , Yuma Agricultural Center, 2002- 2003.

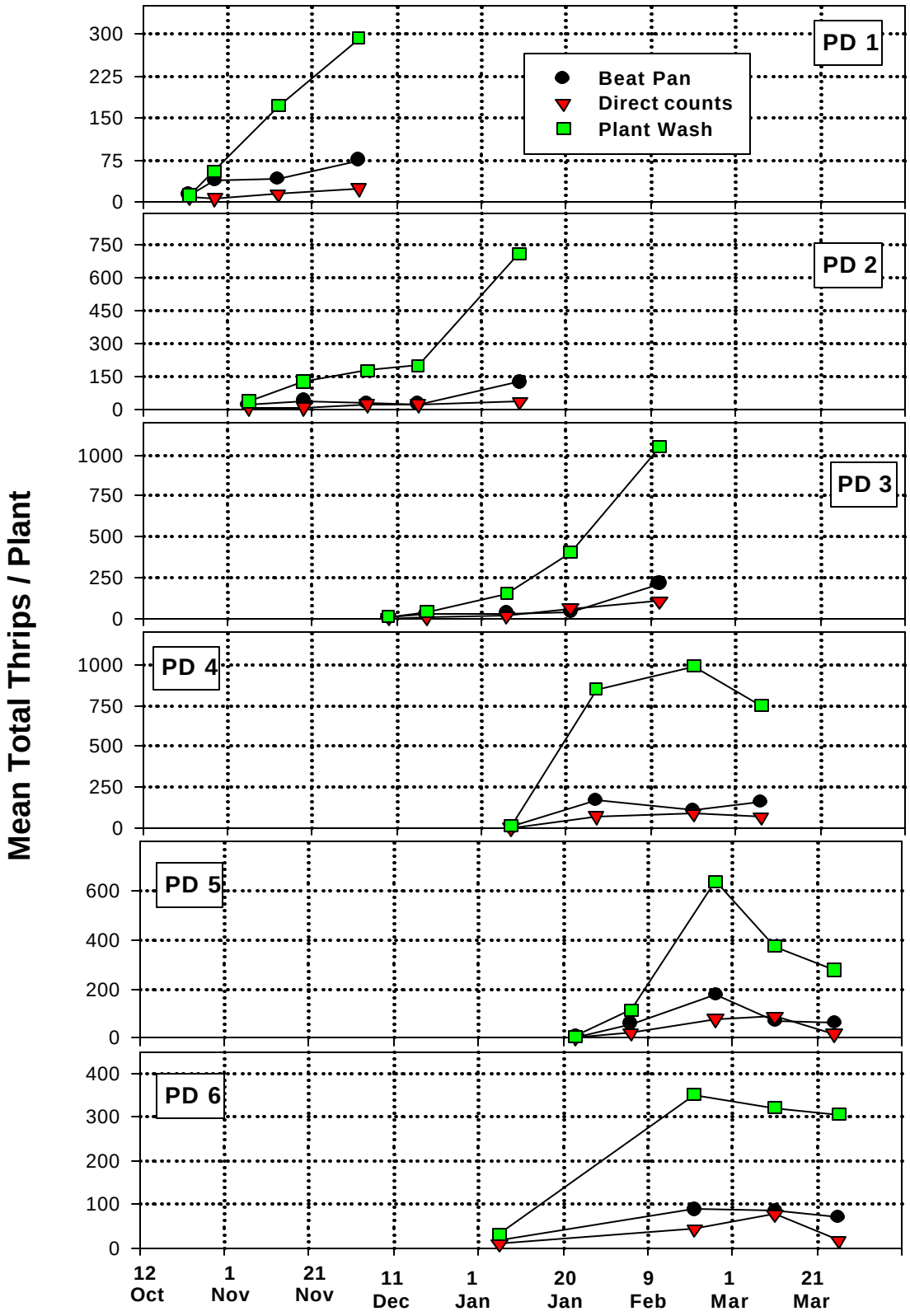


Figure 10. Population trends of thrips adults estimated with yellow and blue sticky traps in six experimental lettuce plantings , Yuma Agricultural Center, 2002- 2003.

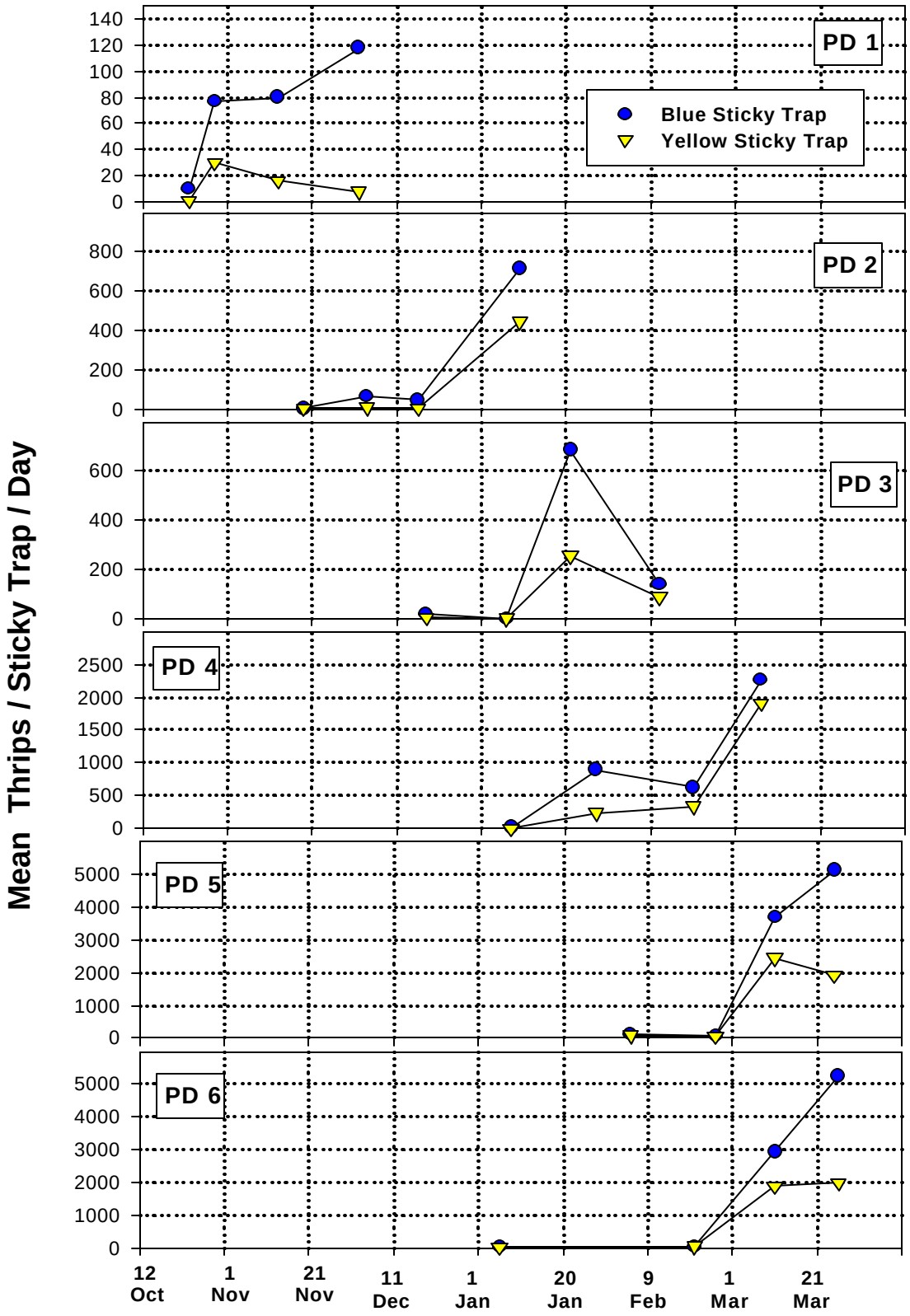


Figure 11. Correlation of beat pan and direct counts of thrips adults with absolute estimates with plant washes.

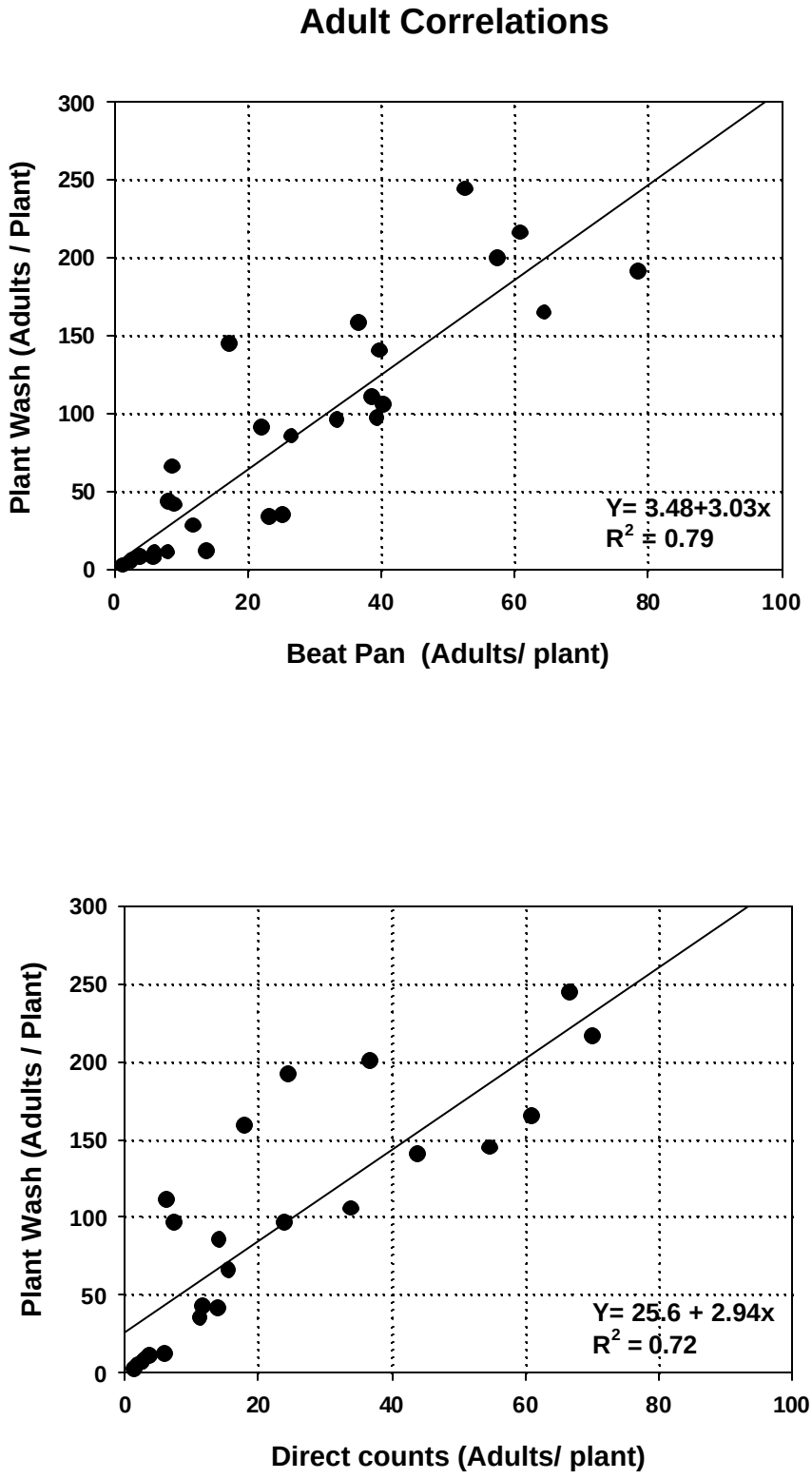
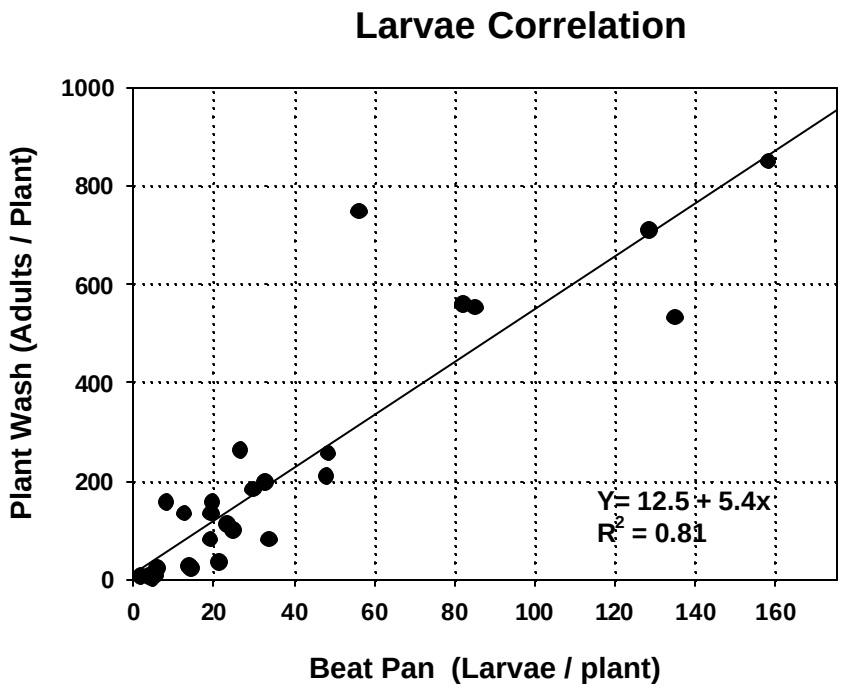


Figure 12. Correlation of beat pan and direct counts of thrips larvae with absolute estimates with plant washes



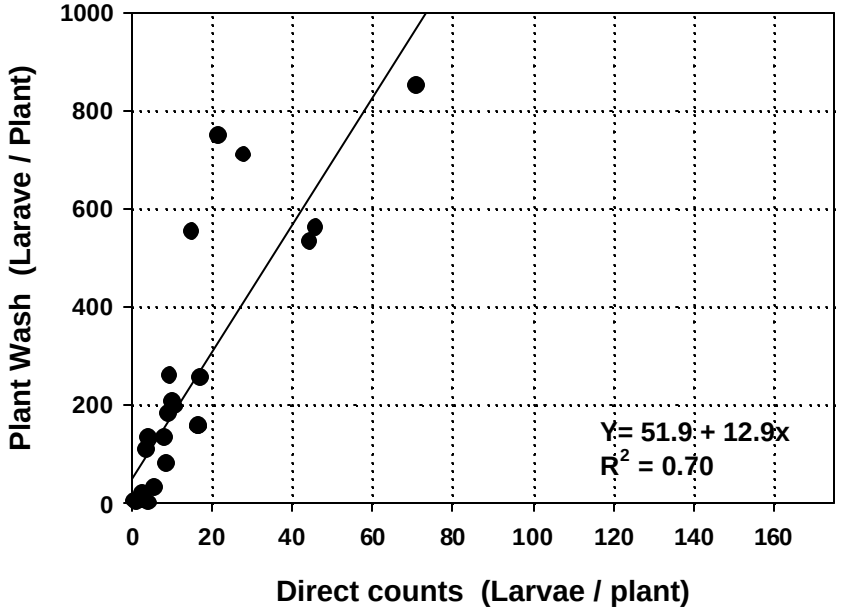


Figure 13. Correlation of beat pan and direct counts of total thrips with absolute estimates with plant washes

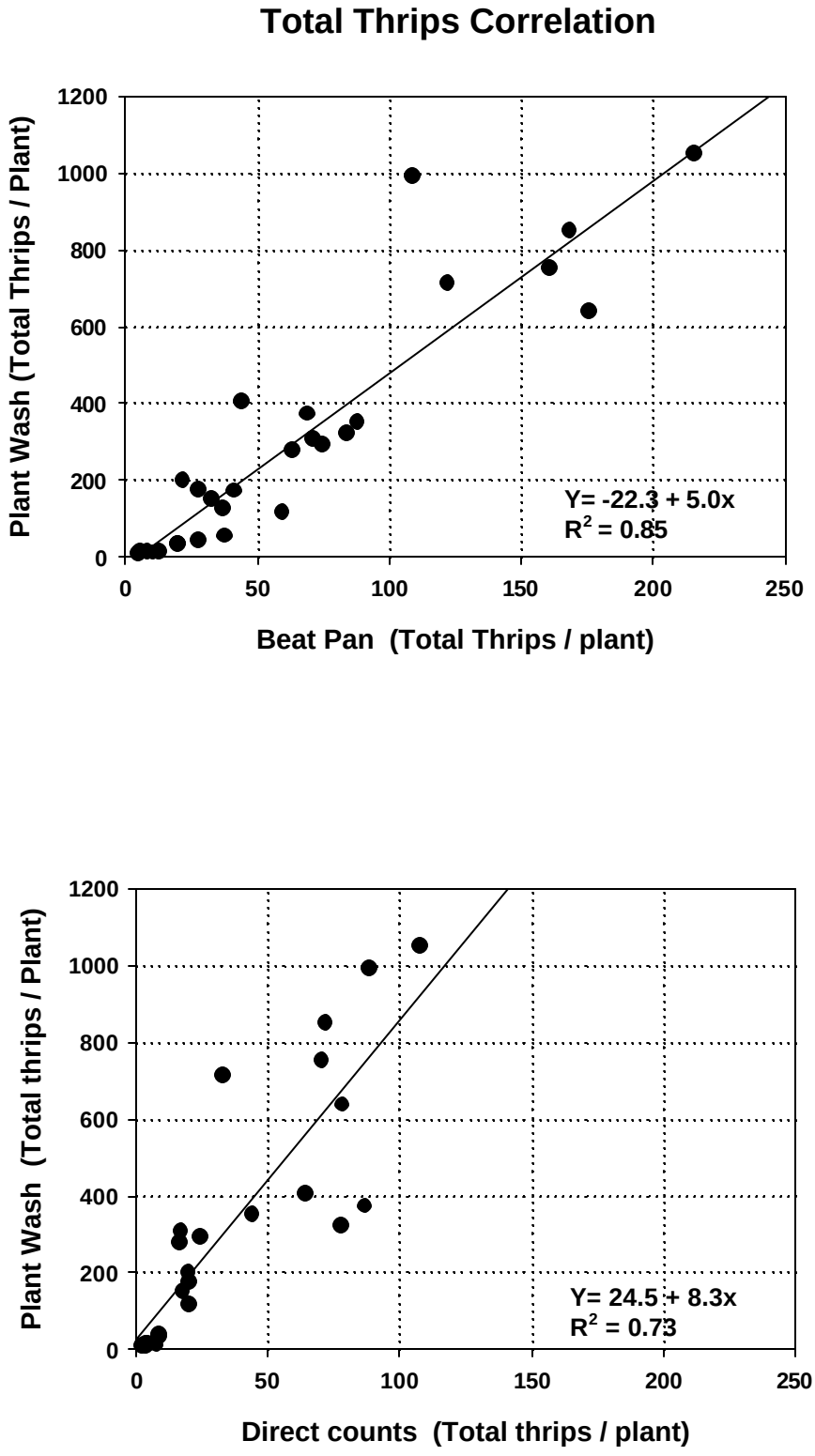
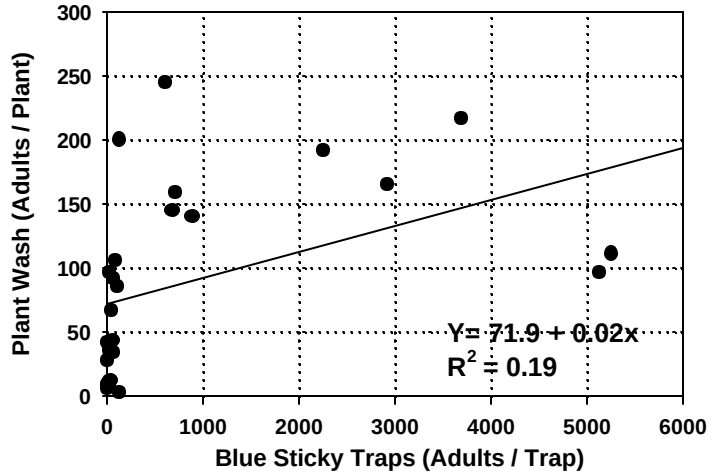
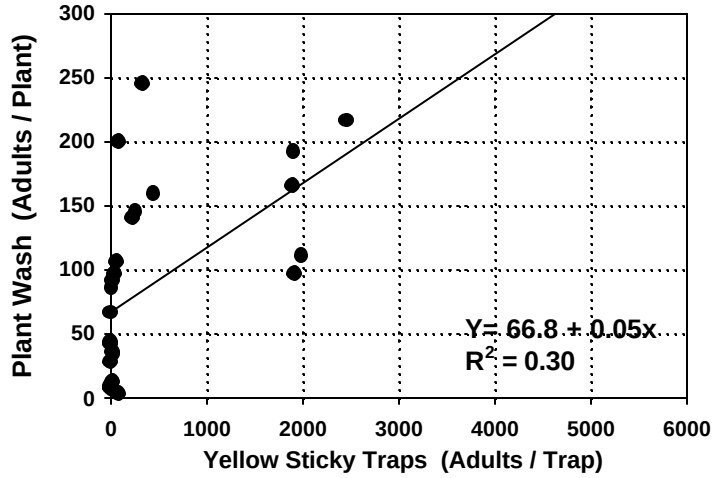


Figure 14. Correlation between blue and yellow sticky traps with absolute estimates of thrips with plant washes





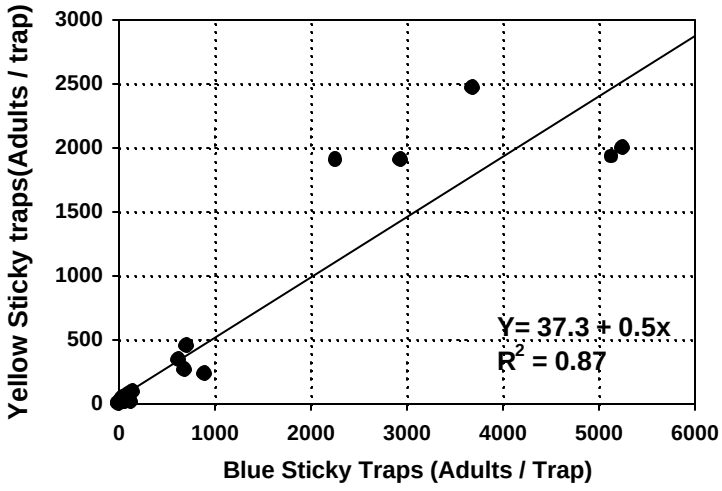


Table 2. Seasonal mean number of thrips adults per plant, RV and RNP values associated with 3 sampling methods on crop stages in head lettuce, Yuma Agricultural Center, 2002-2003.

Crop stage	Sampling method	Mean " SD	RV " SD	Cost [a]	RNP [b]
Thinning	Beat pan	6.6 " 4.3 a	18.7 " 2.7 a	0.07	76.9
	Direct count	3.2 " 1.6 b	20.6 " 4.8 a	0.04	121.9
	Plant wash	8.5 " 3.5 a	15.0 " 9.2 a	0.25	26.3
Pre-heading	Beat pan	27.4 " 14.5 b	10.6 " 4.8 b	0.16	58.8
	Direct count	21.2 " 15.6 b	18.6 " 4.9 a	0.04	133.3
	Plant wash	74.2 " 46.2 a	10.9 " 5.6 b	0.45	20.4
Early heading	Beat pan	37.8 " 24.4 b	12.9 " 5.0 a	-	-
	Direct count	46.5 " 26.3 b	9.4 " 6.1 a	-	-
	Plant wash	154.4 " 69.2 a	8.3 " 2.2 a	-	-
Harvest - Frame	Beat pan	22.4 " 8.0 b	18.1 " 4.7 a	0.18	31.3
	Direct count	6.2 " 2.8 b	29.6 " 14.0 a	0.04	55.5
	Plant wash	80.5 " 32.8 a	10.1 " 2.0 b	0.70	14.1
Harvest - Head	Beat pan	22.9 " 12.2 b	12.2 " 5.5 a	0.22	38.5
	Direct count	11.7 " 9.3 b	13.7 " 7.5 a	0.04	181.8
	Plant wash	59.8 " 20.4 a	15.3 " 6.3 a	0.75	8.7

Means followed by the same letter are not significantly different *(AOV, $p<0.05$)*

[a] Cost (mean no. person-hours to collect and process each plant sample).

[b] RNP=Relative net precision = 100/(RV x cost)

Table 3. Seasonal mean number of thrips larvae per plant, RV and RNP values associated with 3 sampling methods on crop stages in head lettuce, Yuma Agricultural Center, 2002-2003.

Crop stage	Sampling method	Mean " SD	RV " SD	Cost [a]	RNP [b]
Thinning	Beat pan	5.8 " 4.3 a	34.5 " 12.7 a	0.07	41.4
	Direct count	2.2 " 1.3 a	36.3 " 15.0 a	0.04	68.9
	Plant wash	10.2 " 9.8 a	35.6 " 22.9 a	0.25	11.2
Pre-heading	Beat pan	62.5 " 54.9 b	19.3 " 8.9 a	0.16	32.3
	Direct count	16.9 " 16.7 b	29.0 " 12.3 a	0.04	86.2
	Plant wash	287.3 " 274.3 a	17.8 " 10.7 a	0.45	12.5
Early heading	Beat pan	23.8 " 17.2 b	17.2 " 6.8 ab	-	-
	Direct count	12.5 " 6.9 b	22.0 " 5.5 a	-	-
	Plant wash	255.6 " 10.2 a	10.2 " 6.4 b	-	-
Harvest - Frame	Beat pan	43.1 " 28.7 b	14.7 " 11.4 a	0.18	37.8
	Direct count	20.1 " 21.8 b	16.9 " 11.4 a	0.04	147.9
	Plant wash	278.8 " 200.5 a	14.2 " 5.9 a	0.70	10.1
Harvest - Head	Beat pan	29.7 " 19.7 b	16.6 " 8.3	0.22	27.4
	Direct count	6.9 " 4.6 b	21.1 " 10.1	0.04	118.5
	Plant wash	145.6 " 76.0 a	16.3 " 6.1	0.75	8.2

Means followed by the same letter are not significantly different *(AOV, $p<0.05$)*

[a] Cost (mean no. person-hours to collect and process each plant sample).

[b] RNP=Relative net precision = 100/(RV x cost)

Table 4. Seasonal mean number of total thrips per plant, RV and RNP values associated with 3 sampling methods on crop stages in head lettuce, Yuma Agricultural Center, 2002-2003.

Crop stage	Sampling method	Mean " SD	RV " SD	Cost [a]	RNP [b]
Thinning	Beat pan	12.4 " 6.6 ab	14.7 " 6.0 a	0.07	97.2
	Direct count	5.4 " 2.5 b	14.1 " 4.2 a	0.04	177.3
	Plant wash	18.6 " 11.8 a	17.5 " 10.0 a	0.25	22.9
Pre-heading	Beat pan	89.9 " 66.9 b	13.5 " 5.4 a	0.16	46.3
	Direct count	38.6 " 31.0 b	14.5 " 4.1 a	0.04	172.4
	Plant wash	361.4 " 318.5 a	12.7 " 5.5 a	0.45	17.5
Early heading	Beat pan	61.6 " 32.0 b	9.8 " 3.9 a	-	-
	Direct count	58.9 " 32.8 b	9.9 " 4.5 a	-	-
	Plant wash	410.0 " 299.5 a	8.2 " 4.0 a	-	-
Harvest - Frame	Beat pan	65.5 " 32.4 b	11.5 " 6.1 a	0.18	48.3
	Direct count	26.3 " 23.8 b	14.3 " 7.3 a	0.04	174.8
	Plant wash	359.2 " 227.8 a	11.2 " 4.4 a	0.70	12.8
Harvest - Head	Beat pan	52.1 " 29.0 b	12.4 " 4.3 a	0.22	36.7
	Direct count	18.7 " 13.0 b	12.4 " 4.9 a	0.04	201.6
	Plant wash	205.4 " 94.5 a	11.3 " 3.5 a	0.75	11.8

Means followed by the same letter are not significantly different *(AOV, $p<0.05$)*

[a] Cost (mean no. person-hours to collect and process each plant sample).

[b] RNP=Relative net precision = 100/(RV x cost)

Table 5. Mean number of thrips per plant estimated by 3 sampling methods in insecticide efficacy trials, Yuma Agicultural Center, Head Lettuce - I West (6 Feb, Pre-heading stage)

	Avg. no. WFT / plant								
Spray	**Adult**			**Larvae**			**Total thrips**		
Interval [a]	**Direct**	**Beat**	**Wash**	**Direct**	**Beat**	**Wash**	**Direct**	**Beat**	**Wash**
14-day	3.8 b	5.2 b	8.3 b	2.8 b	1.9 b	6.7 b	6.7 b	7.1 b	14.9 b
7- day	2.0 b	2.7 b	4.8 b	1.2 b	1.7 b	3.5 b	3.3 c	4.3 b	8.3 b
Untreated	10.7 b	11.8 a	28.3 a	9.4 a	13.3 a	45.6 a	20.2 a	25.2 a	73.9 a

Means followed by the same letter are not significantly different ($p<0.05$)

[a] 7 –d ay spray interval received 3 applications; 14 day spray interval received 2 applications prior to sample.

Table 6. Mean number of thrips per plant estimated by 3 sampling methods in insecticide efficacy trials, Yuma Agicultural Center, Head Lettuce - I West (12 Mar, Harvest stage)

	Avg. no. WFT / plant								
Spray	**Adult**			**Larvae**			**Total thrips**		
Interval [a]	**Direct**	**Beat**	**Wash**	**Direct**	**Beat**	**Wash**	**Direct**	**Beat**	**Wash**
14-day	7.1 a	26.0 a	88.8 b	3.3 b	31.8 b	173.6 b	10.3 a	57.8 b	261.7 a
7- day	9.3 a	30.0 a	128.8 a	2.5 b	21.7 b	103.8 c	11.8 a	51.3 b	232.6 a
Untreated	6.0 a	27.0 a	60.7 b	12.3 a	58.5 a	264.3 a	18.3 a	85.5 a	325.5 a

Means followed by the same letter are not significantly different ($p<0.05$)

[a] 7 –d ay spray interval received 3 applications; 14 day spray interval received 2 applications prior to sample.

Table 7. Mean number of thrips per plant estimated by 3 sampling methods in insecticide efficacy trials, Yuma Agicultural Center, Head Lettuce -I East- (6 Feb, Pre-heading stage)

	Avg. no. WFT / plant								
Spray	**Adult**			**Larvae**			**Total thrips**		
Interval [a]	**Direct**	**Beat**	**Wash**	**Direct**	**Beat**	**Wash**	**Direct**	**Beat**	**Wash**
14-day	2.6 b	3.8 b	6.6 b	0.7 b	1.9 b	4.9 b	5.5 b	5.7 b	11.5 b
7- day	4.8 b	3.6 b	6.3 b	0.6 b	1.0 b	4.3 b	3.1 b	4.7 b	10.6 b
Untreated	12.8 a	15.5 a	29.9 a	9.4 a	12.4 a	49.7 a	22.3 a	27.9 a	79.6 a

Means followed by the same letter are not significantly different ($p<0.05$)

[a] 7 –d ay spray interval received 3 applications; 14 day spray interval received 2 applications prior to sample.

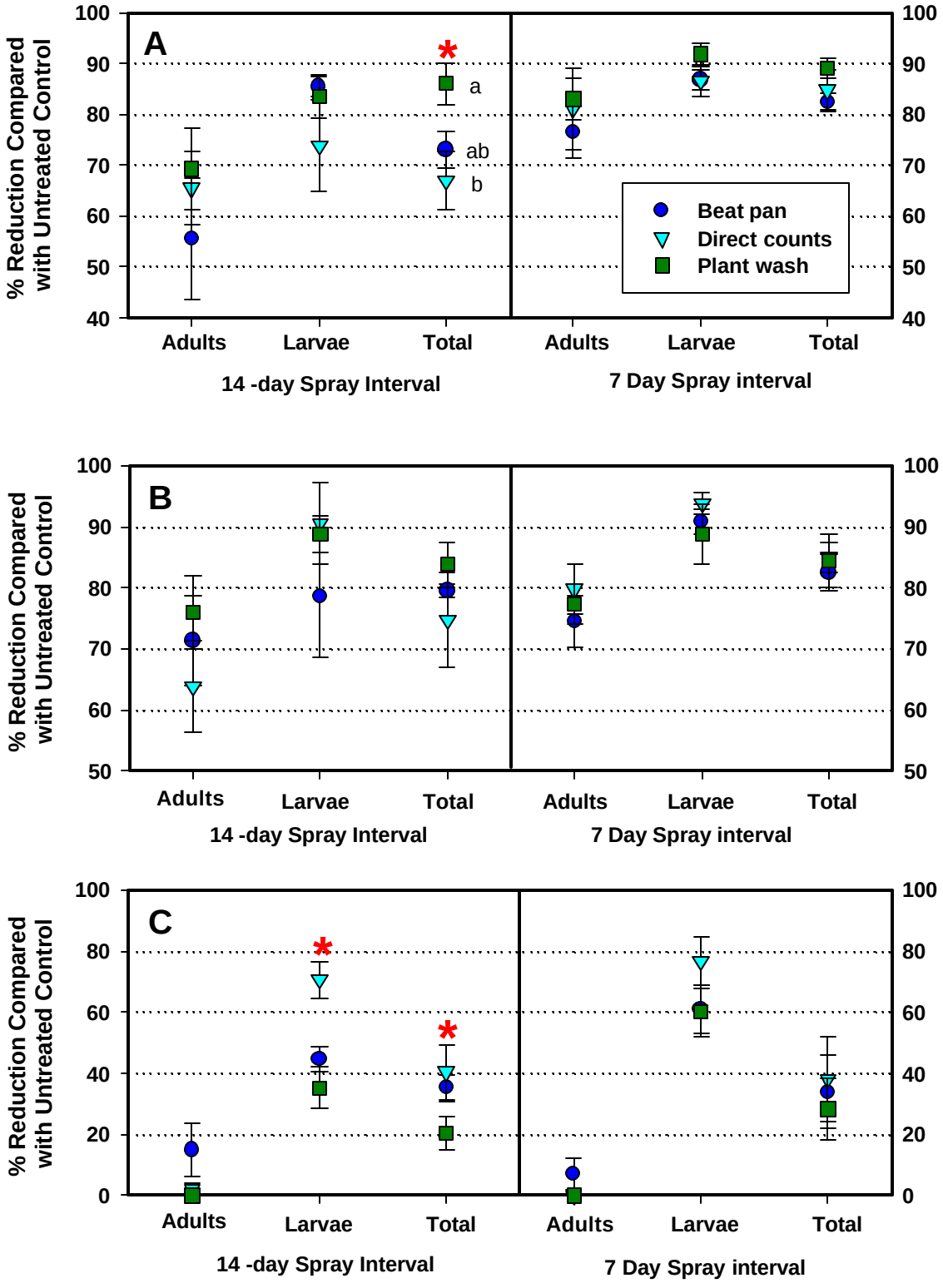


Figure 15. Average % control of thrips following two spray regimes on head lettuce as measured by beat pan, direct counts and plat wash sampling A=Head Lannate I -West (pre-heading stage); B=Head Lettuce - I East (Pre-heading stage); C= Head Lettuce -I West (Harvest stage)
* =significant treatment differences, Dunnetts Test ($p<0.05$)

Table 8. Mean number of thrips per plant estimated by beat pan and plant washes sampling in an insecticide efficacy trial, Head Lettuce II (early heading stage)

	Avg. no. WFT / plant			
	Adult		Larvae	
TMT	Beat	Wash	Beat	Wash
Success 6 oz	21.7 ab	70.2 a	11.4 b	55.3 b
Success 10 oz	18.2 abc	69.2 a	11.1 b	29.1 b
Success 5 oz +Mustang 4 oz	14.6 bc	41.6 a	11.8 b	44.1 b
Lannate 0.7 lb + mustang 4 oz	11.1 c	56.6 a	5.7 b	35.8 b
Untreated	22.8 a	71.3 a	54.3 a	240.4 a

Means followed by the same letter are not significantly different ($p<0.05$)

Table 9. Mean number of thrips per plant estimated by beat pan and plant washes sampling in an insecticide efficacy trial, Romaine (Pre-harvest stage)

	Avg. no. WFT / plant			
	Adult		Larvae	
TMT	Beat	Wash	Beat	Wash
Success 6 oz	11.4 ab	53.7 a	7.0 b	33.9 b
Success 10 oz	10.2 abc	38.4 b	5.9 b	19.0 b
Success 5 oz +Mustang 4 oz	7.6 c	26.3 c	8.3 b	45.6 b
Lannate 0.7 lb + mustang 4 oz	8.4 bc	26.6 c	3.9 b	23.8 b
Untreated	12.1 a	55.2 a	52.2 a	209.5 a

Means followed by the same letter are not significantly different ($p<0.05$)

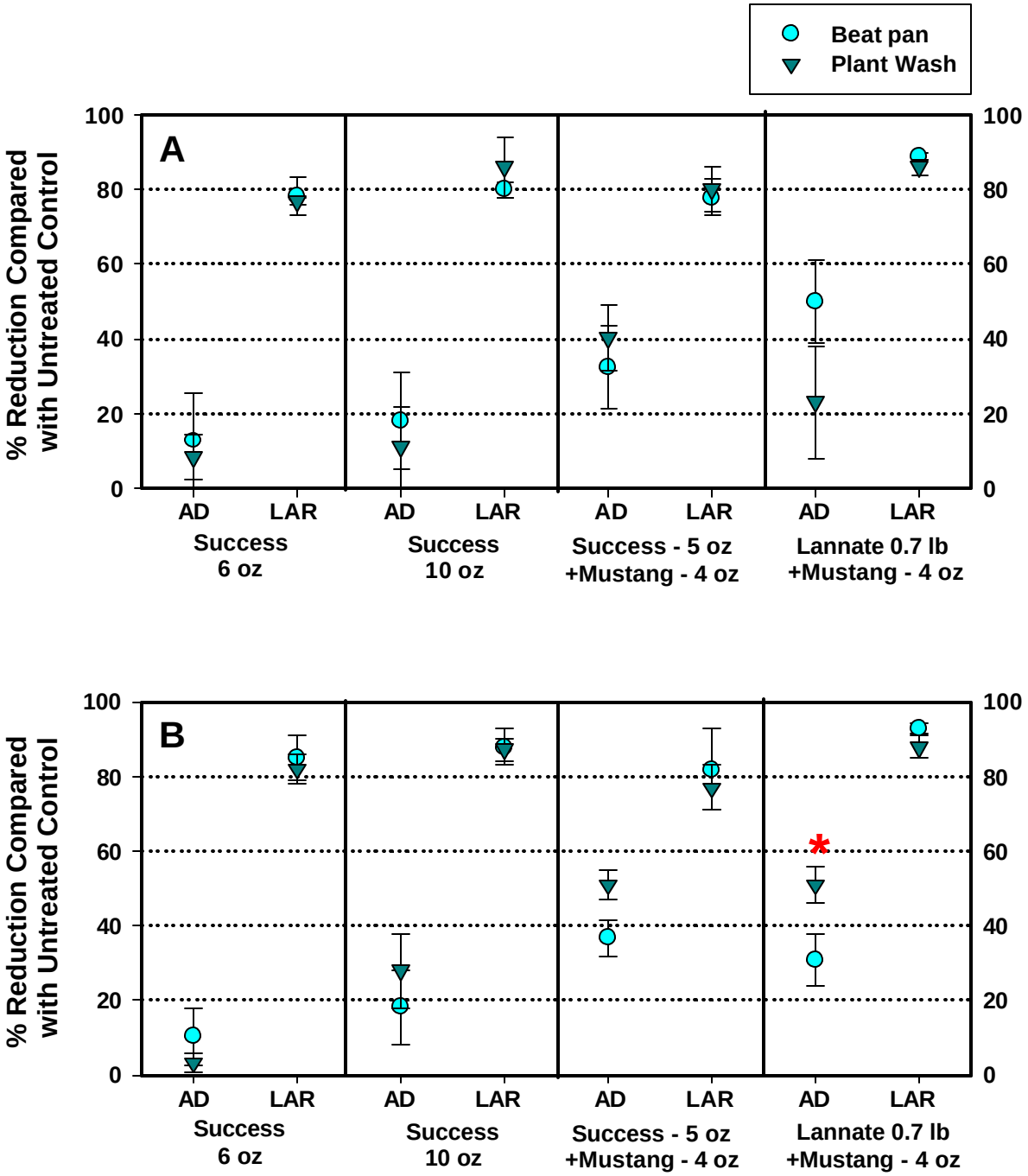


Figure 16. Average % control of thrips in insecticide treatmenst on head lettuce as measured by beat pan and plant wash sampling. A=Head lettuce II (Early heading stage); B= Romaine (pre-harvest stage). * =Significant treatment differences (paired t test, $p<0.05$).

Table 10. Trial 1 Preheading stage (12-14 lvs)

Spray Interval	Insectcide treatment	Thips Densities (mean/plant)			Damage	Midrib bronzing (%	% Leaves with Damage Rating		
		Adults	Larvae	Total	Rating	leaves)	1 or >	2 or >	3 or >
Weekly - 3 sprays	Success 10 oz	6.3 b	4.3 b	10.7 b	1.2 c	48.0 b	92.5 a	25.0 c	1.5 c
Biweekly - 2 sprays	Success 10 oz	6.6 b	4.9 b	11.5 b	1.5 b	60.7 b	93.0 a	45.5 b	13.0 b
Untreated	-	29.9 a	49.7 a	79.5 a	2.7 a	82.0 a	99.0 a	80.0 a	61.5 a

Table 11. Trial 2 Preheading stage (12-14 lvs)

Spray Interval	Insectcide treatment	Thips Densities (mean/plant)			Damage	Midrib bronzing (%	% Leaves with Damage Rating		
		Adults	Larvae	Total	Rating	leaves)	1 or >	2 or >	3 or >
Weekly - 3 sprays	Lannate-Success rotation	4.8 b	3.5 b	8.3 b	1.0 c	65.3 a	78.7 b	22.5 c	2.3 b
Biweekly - 2 sprays	Lannate-Success rotation	8.3 b	6.7 b	14.9 b	1.4 b	73.7 a	87.3 ab	43.8 b	10.0 b
Untreated	-	28.3 a	45.5 a	73.9 a	2.5 a	78.3.0 a	92.50 a	72.3 a	51.0 a

Table12 . Trial 2 Harvest stage

	Thips Densities (mean/plant)			Avg. Damage Rating			Midrib Bronzing (% leaves)		
Spray Interval	**Adults**	**Larvae**	**Total**	**Wrapper**	**Cap**	**Butt**	**Wrapper**	**Cap**	**Butt**
Weekly - 8 sprays	108.0 a	103.8 c	211.8 b	1.2 c	1.0 b	0.3 b	37 c	14 c	8.3 c
Biweekly - 4 sprays	92.3 b	173.6 b	265.9 b	2.0 b	1.6 b	1.3 ab	68 b	68 b	75 b
Untreated	75.7 b	270.3 a	346.0 a	3.9 a	2.9 a	2.0 a	98 a	100 a	100 a

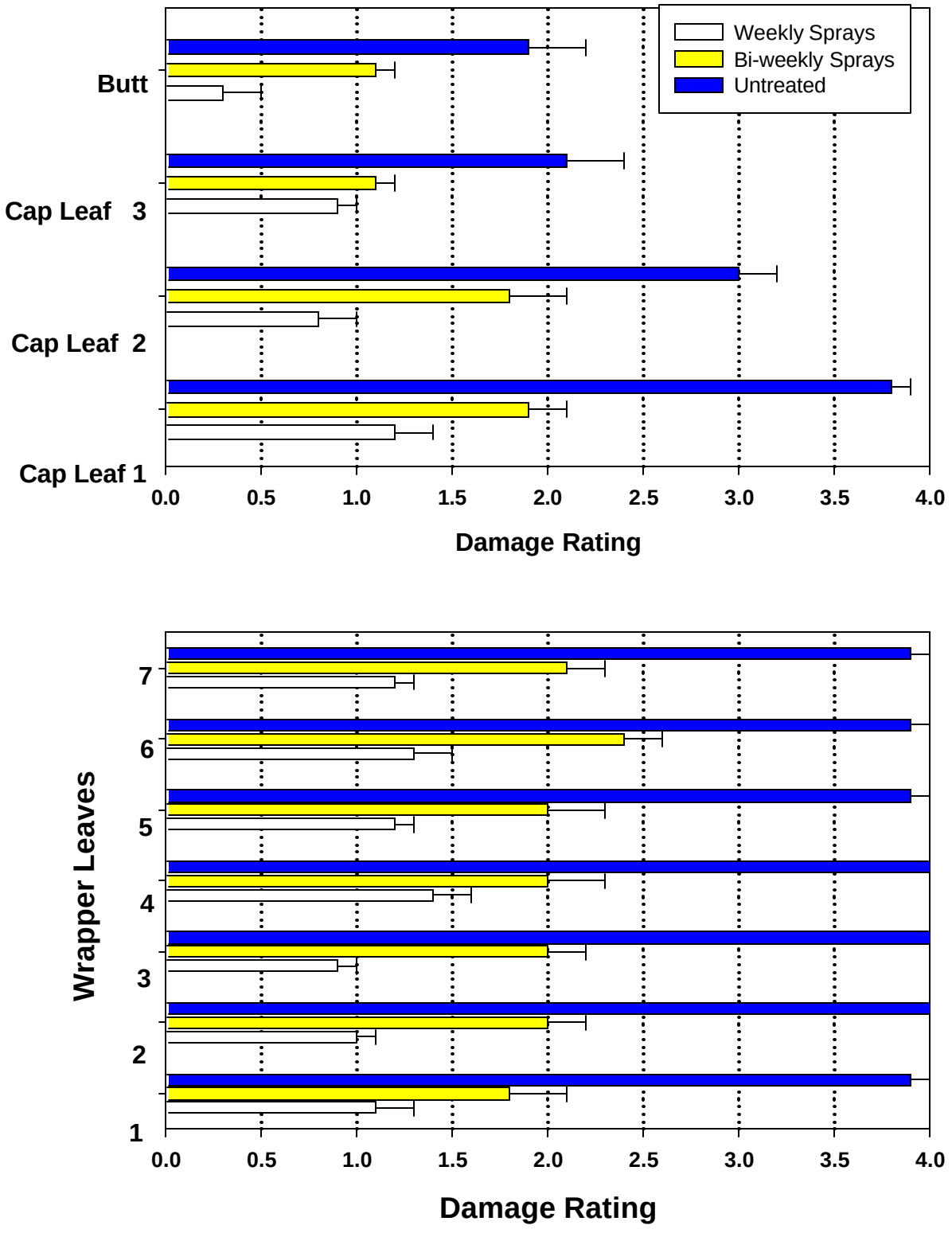


Figure 18. Distribution of thrips scarring on head lettuce wrapper leaves and heads at harvest

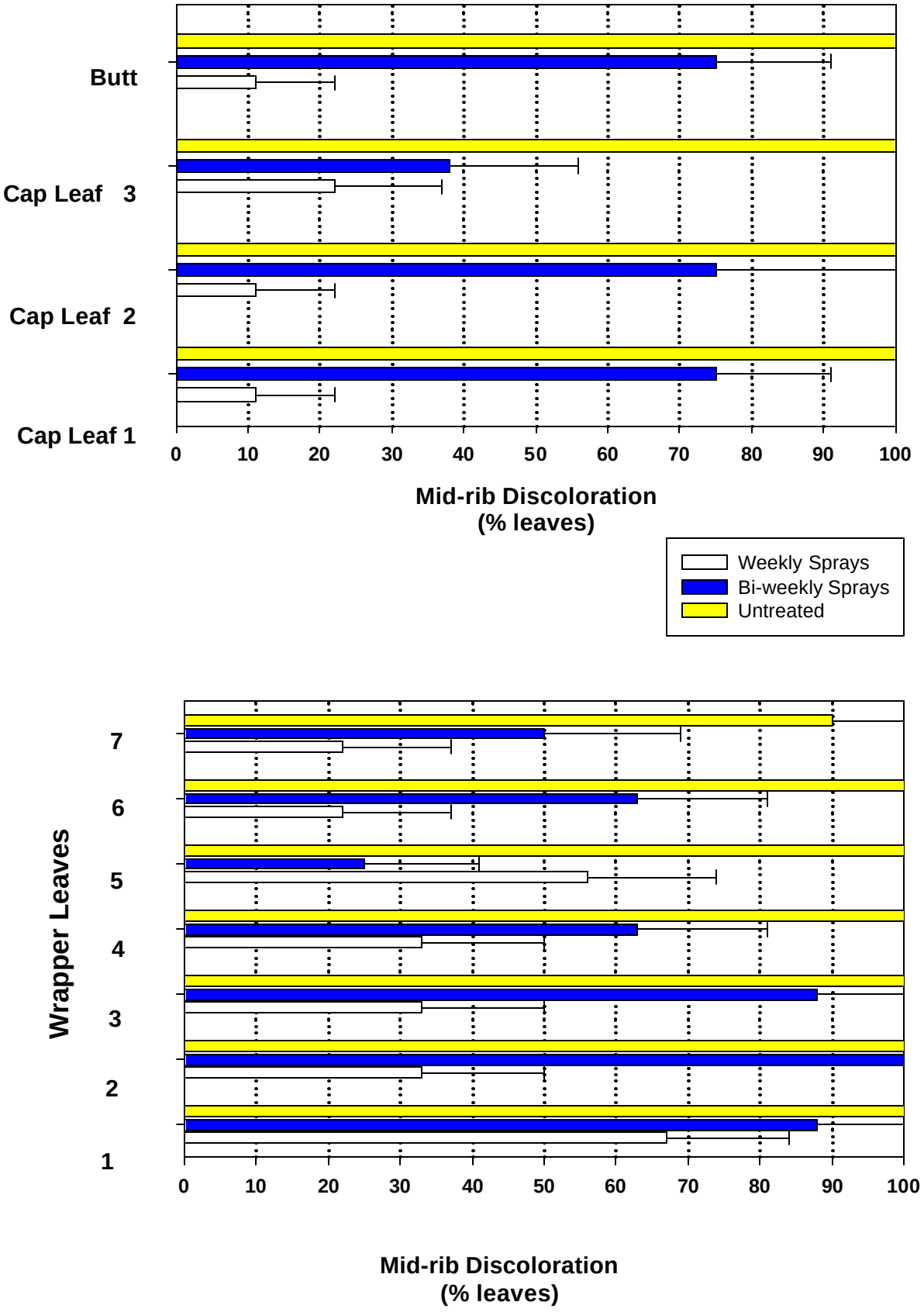


Figure 18. Distribution of rib bronzing on head lettuce wrapper leaves and heads at harvest

Table 14. Thrips abundance on Romaine plants at Harvest

	Thrips Densities at Harvest (mean / plant)		
Treatment	**Adults**	**Larvae**	**Total Thrips**
Caged Plants	17.3 c	41.8 d	59.1 d
Weekly sprays	153.2 b	389.3 c	542.6 c
Bi-weekly sprays	203.7 ab	599.3 b	803.0 b
Untreated	230.8 a	1122.4 a	1353.2 a

Table 15. Thrips damage and romaine plant yields at Harvest .

	Leaf Damage indices		Yield (mean/plant)			
					Plant weight (g)	
Treatment	**Scarring rating**	**Midrib bronzing (% leaves)**	**Total leaves**	**Marketable leaves**	**Whole**	**Trimmed**
Caged Plants	0.13 d	4.6 b	40.4 a	31.0 a	34.8 a	18.6 a
Weekly sprays	0.89 c	59.2 a	40.2 a	15.8 b	30.3 b	11.7 b
Bi-weekly sprays	2.09 b	66.8 a	38.0 b	12.5 c	25.7 c	7.7 c
Untreated	2.36 a	64.6 a	35.6 c	12.2 c	22.7 c	7.3 c

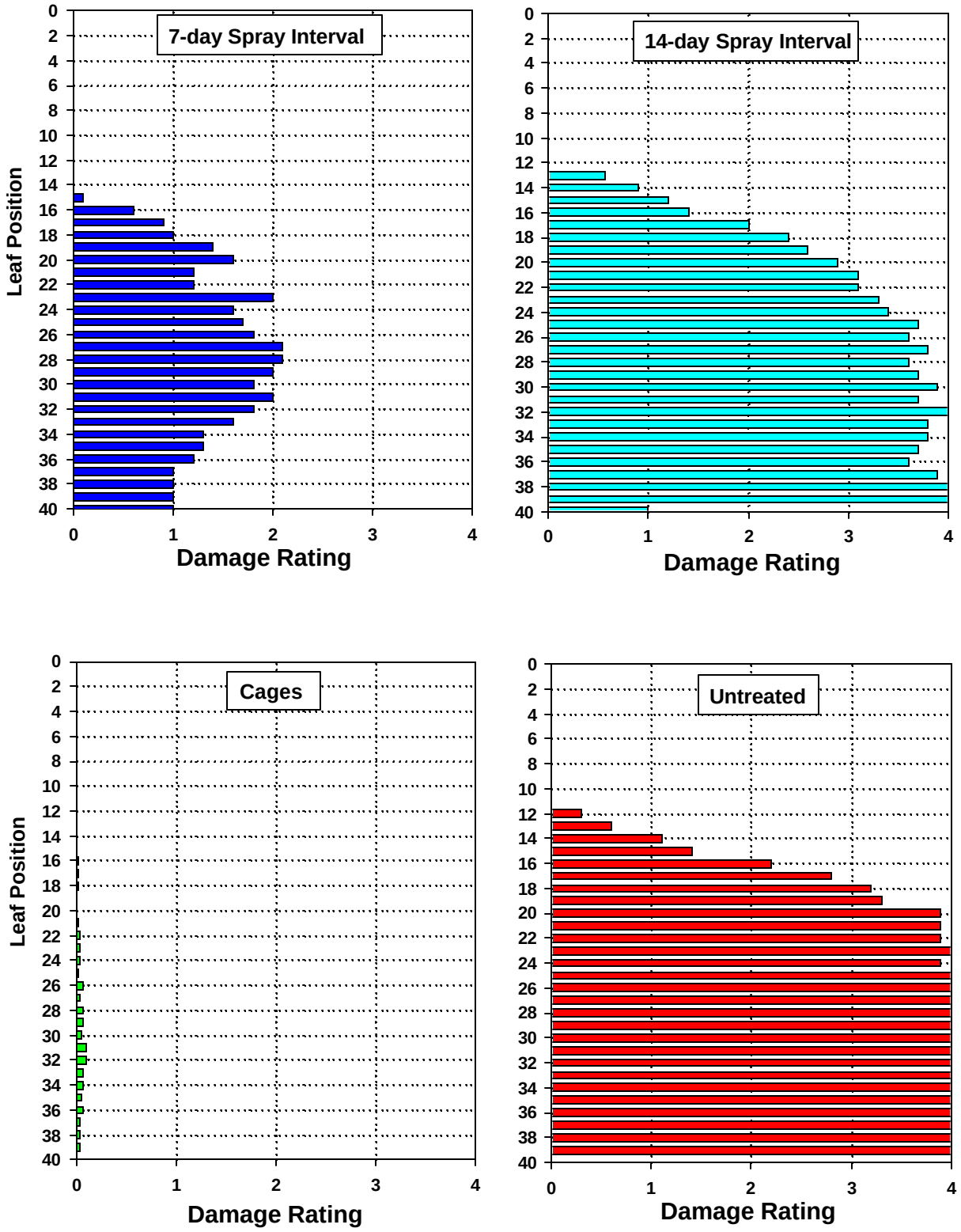


Figure 19.Within plant distribution of thrips damage(scarring) on romaine plants at harvest

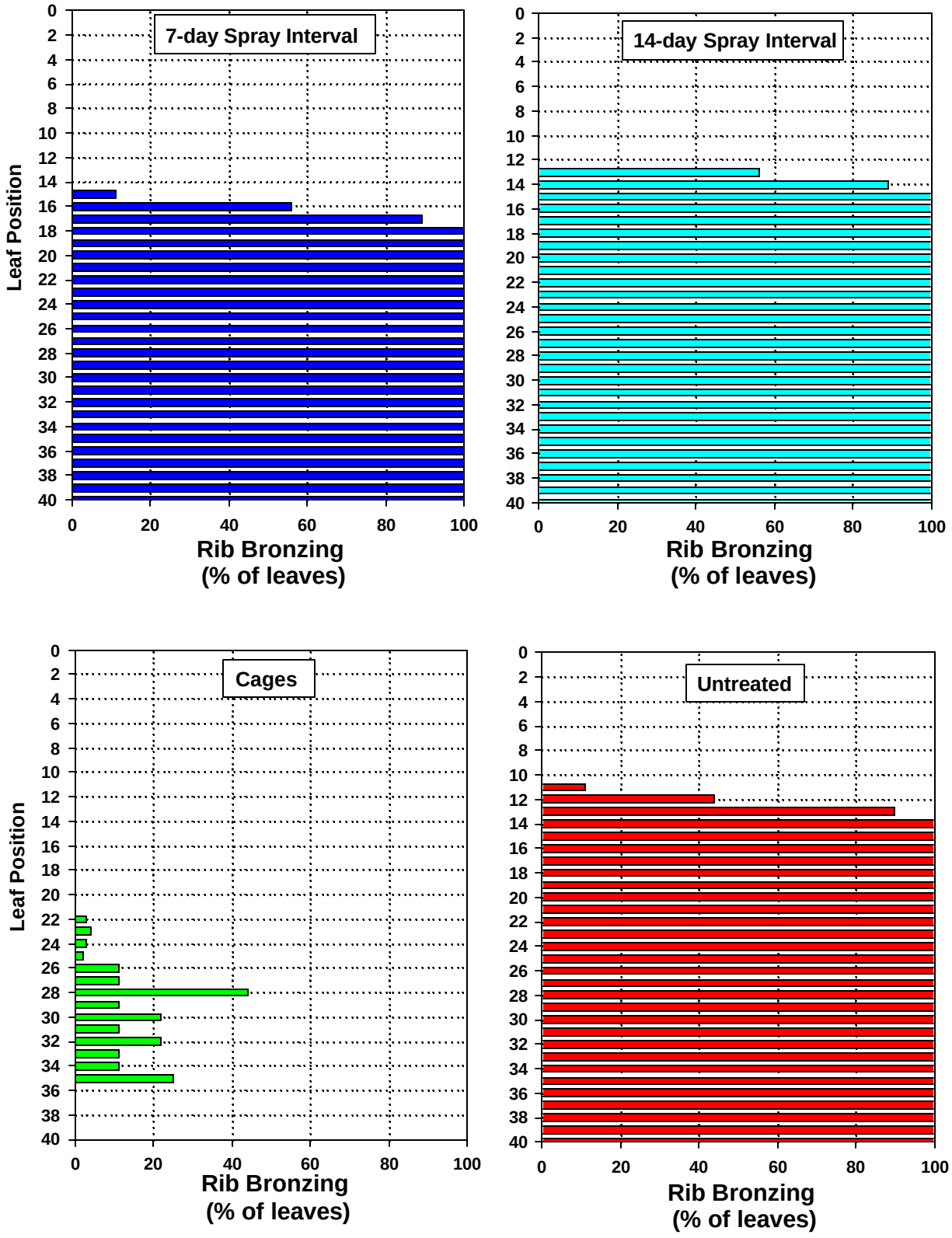


Figure 20. Within plant distribution of rib bronzing on romaine plants at harvest